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CHAPEL HILL, N. C., U. S. A.

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Volume 47 January, 1932 No. 1

PROCEEDINGS OF THE THIRTIETH ANNUAL MEETING OF THE NORTH CAROLINA ACADEMY OF SCIENCE

STATE COLLEGE, RALEIGH, N. C., MAY 8 AND 9, 1931

The thirtieth annual meeting of the North Carolina Academy of Science was held at State College, May 8 and 9, 1931. The meeting was called to order at 9:30 A.M., on May 8, by the president, Dr. W. F. Prouty. The reading of papers was begun and continued until 12:15 P.M., when the Academy adjourned for lunch, after the appointment of the following committees by the president:

Auditing: E. H. Hall, J. L. Stuckey, Otto Stuhlman, Jr.

Nominating: Z. P. Metcalf, H. B. Arbuckle, Bert Cunningham.

General Resolutions: A. S. Pearse, Miss Ella Martin, C. E. Preston.

The reading of papers was resumed at 2:00 P.M., and continued until 5:00 P.M., when the Academy went into business session.

The minutes of the previous meeting were approved as published in the *Journal of the Elisha Mitchell Scientific Society*.

Reports were called for from the various committees.

The executive committee, consisting of W. F. Prouty, president of the Academy; P. M. Ginnings, vice-president; H. R. Totten, secretary and treasurer; F. A. Wolf, Bert Cunningham, and W. L. Porter, reported as follows:

"The executive committee met at Chapel Hill on May 7, and again at Raleigh on May 8, with all members present.

"The committee passed favorably upon the request of the secretary to add to the general program a title to a paper received too late for publication from J. H. Swartz entitled, 'Some Factors Involved in Resistivity Methods of Geophysical Exploration.'

"The committee also passed favorably upon the request of E. R. C. Miles to change the title of his paper to be presented to the mathematics section to read 'A Poisson-Stieltjes Integral for the Heat Equation.'

"The committee reports as elected to membership since the last annual meeting the following:

Addoms, Miss Ruth, Instructor in Botany, Duke University.
Alexander, A. E., Graduate Student in Geology, University of North Carolina.
Bostian, C. H., Assistant Professor of Zoology, State College.
Brown, E. J., Assistant in Physics, State College.
Brown, Frank N., Assistant in Biology, Davidson College.
Constable, Ernest W., Graduate Student in Chemistry and Biology, University of North Carolina.
Constant, F. W., Instructor in Physics, Duke University.
Creager, D. B., Instructor in Botany, Duke University.
Dale, Miss Julia, Assistant Professor of Mathematics, Duke University.
Dodson, Clinton F., Professor of Biology, Campbell College.
Dressel, F. G., Instructor in Mathematics, Duke University.
Greenwood, J. A., Instructor in Mathematics, Duke University.
Hargitt, George T., Professor of Zoology, Duke University.
Hooker, C. W., Assistant in Zoology, Duke University.
Lancaster, F. W., Assistant Professor of Physics, State College.
Lutz, J. F., Assistant Professor of Soils, State College.
Martin, Irving L., Instructor in Geology, University of North Carolina.
Maurice, C. S., Assistant in Geology, University of North Carolina.
McNutt, Miss Dorothea, Assistant in Biology, Greensboro College.
Morse, W. C., Visiting Professor of Geology, University of North Carolina.
Norburn, Miss Martha E., Graduate Student in Geology, University of North Carolina.
Perry, Mrs. Louise M., Practicing Physician, Asheville, N. C.
Russell, Cloyd H., Graduate Student in Chemistry, State College.
Scott, E. R., Assistant in Geology, University of North Carolina.
Showalter, Merle F., Associate Professor of Education, State College.
Smith, B. E., Assistant in Botany, University of North Carolina.
Smith, G. Wallace, Associate Professor of Engineering, University of North Carolina.
Stokes, Miss Ruth, Assistant in Mathematics, Duke University.
Taylor, Otis B., Assistant Professor of Zoology, State College.
Thomas, J. Miller, Assistant Professor of Mathematics, Duke University.
Wager, Miss Martha, Mars Hill College.
Williams, Carlos F., Associate Horticulturist, State College.
Williams, L. L., Teaching Fellow in Zoology, University of North Carolina.
Yates, R. E. L., Professor of Mathematics, State College.

Reinstated to Membership:
J. H. Beaumont, Professor of Horticulture, State College.

J. G. Boomhour, Professor of Physics, Meredith College.
Cameron, E. A., Instructor in Mathematics, University of North Carolina.
Henderson, Archibald, Kenan Professor of Mathematics, University of North Carolina.
Hoyle, V. A., Assistant Professor of Mathematics, University of North Carolina.
Kopf, Miss Minnie, Professor of Home Economics, Missouri Valley College, Marshall, Mo.
Nielsen, Walter M., Assistant Professor of Physics, Duke University.
Williams, Maude, Instructor in Psychology, North Carolina College for Women.
Willis, L. G., Professor of Agriculture, State College.

Lost by death:
Cain, William, Kenan Professor Emeritus of Mathematics in the University of North Carolina. Died December 6, 1930.
Nowell, John William, Professor of Chemistry in Wake Forest College. Died November 25, 1930.

Lost by resignation:
Klemm, Ethel M.
McDougall, William.
O'Donnell, Annie M.

Lost after removal from the state:
Braudwell, Leslie J.
Carroll, R. S.
Hefley, Harold M.
Lyons, Mary
Penney, J. T.
Reed, James W., Jr.
Snyder, L. H.

Dropped from the roll for non-payment of dues:
Eighteen former members.

"The committee accepted the invitation of Wake Forest College to hold the thirty-first annual meeting in Wake Forest.

The executive committee made the following recommendations to the Academy:

1. "That all bills presented in the Treasurer's report be authorized and paid and that the report be printed when audited.

2. "That H. B. Arbuckle be appointed a committee of one to select the cup to be given to the winner of the high school science essay prize, and that he be authorized to call upon the treasury for as much as $25.00 for the cup; that the Academy send a representative to the commencement of the Greensboro High School to deliver this Academy

prize; and that the Secretary be authorized to select the Academy representative and to pay the expenses of his trip from the Academy funds."

The recommendations of the executive committee were adopted and its report accepted.

The auditing committee reported that they had examined the accounts of the Treasurer for the period May 6, 1930, to May 5, 1931, and had found them correct.

The report of the auditing committee was accepted.

The Treasurer's report was as follows:

Financial Statement

Receipts		Expenditures	
Balance on hand, May 6, 1930..	$601.08	Stationery, postage.....	$66.00
		Printing, mimeographing, multigraphing and addressographing.....	68.67
Dues, for			
1930.....	106.00	Journal of the E. M. S. S.....	300.00
1931.....	282.00	Clerical assistance.....	96.13
		High School Prize.....	23.68
Initiation fees		Expenses of Academy representative to deliver High	
At 1930 Meeting.....	22.00	School Prize.....	5.00
Since 1930 Meeting.....	50.00	Sec'y-Treas. Commission.....	43.60
Interest on Savings.....	20.14	Dues refund to Sec'y-Treas..	2.00
		Protested checks.....	4.50
Allotment from A. A. A. S...	49.00	Telegrams and phone calls...	1.83
			$611.41
Chemists' programs, for			
1930 Meeting.....	5.00		
1931 Meeting.....	5.00		
Sale of membership list.....	1.00		
Protested check replaced.....	2.00	To balance.....	$531.81
	$1,143.22		$1,143.22

Comparison

	1930	1931
Savings account.....	$496.89	$496.89
Checking account.....	92.19	34.92
Cash on hand.....	12.00	0.00
	$601.08	$531.81
To balance (net loss).....		69.27*
		$601.08

* Net loss in 1930, $143.96.

The above report was made as of May 5, 1931.
Submitted by
H. R. Totten, *Secretary-Treasurer.*
Audited by
Otto Stuhlman, Jr.,
Earl H. Hall,
Jasper L. Stuckey.
Date May 8, 1931.

The Treasurer's report was accepted.

The committee on high school science, consisting of Bert Cunningham, chairman; H. B. Arbuckle, R. N. Wilson, C. M. Heck, C. E. Preston, and Miss Lena Bullard reported as follows:

I. Your committee is happy to report that the three objectives outlined when this committee was reorganized have been attained:

1. An increase in the science requirements for graduation from standard high schools;

2. An increase in the equipment for the science courses in high schools; and

3. A more exacting standard for certifying teachers of science in high schools.

In these achievements the committee expresses deep appreciation for the splendid co-operation of the State Department of Education.

With the foregoing opportunities there is an added responsibility, that is; of justifying the time now allotted to science in the high schools. Each member of the Academy, therefore, should render cheerfully any possible service to high school teachers.

II. Every regional meeting of the N. C. E. A., had a Science Section program. These meetings are gaining in interest and attendance, and we believe much good is gained thereby. A greater effort should be made to get the local teachers to discuss current problems.

The state meeting was unusually well attended and problems were freely discussed. This meeting more than doubled the time usually spent in it; and to the members of the committee (3 or more) who were present it appeared profitable.

III. The Committee considered the proposal to affiliate high school science clubs with the Academy, conferring Junior memberships in the Academy on members of such clubs. In view of the uncertain life of such clubs and the additional duties which would be imposed upon the Academy Secretary, your Committee recommends that the Academy should go on record as favoring high school clubs, but as opposing

affiliation. The Committee believes that the high school teacher can be best served personally in this matter.

IV. The Committee recommends that the Academy prize for the year 1932 be granted in the fields of Physics and Chemistry.

V. The Committee recommends that a member of the Academy be selected by the Secretary to deliver the prize offered for the year 1931 to Walter Burke Davis at the commencement of the Greensboro Senior High School.

The report of the committee on high school science was accepted and a very interesting general discussion followed over the present confusion as to the requirements in courses of education and science for high school science teachers. The following motion was passed:

"Moved that the committee on high school science be continued; that they give the prize for the high school essay contest next year; and that they be instructed to find out the nature and number of credits required for a person to qualify as a science teacher in the high schools of the state."

The committee of judges to select the winner of the high school science essay prize, consisting of C. E. Preston, chairman; H. L. Blomquist and B. W. Wells, reported as follows:

"The judges unanimously recommended that the Academy prize be awarded to Walter Burke Davis of the Greensboro Senior High School for an essay entitled 'Snakes of Sumner Township.'

"They suggest that in regulations for future contests a note be inserted urging the avoidance of reproduction of articles and book passages in form similar to their original, and the holding of direct quotations to a minimum."

The report of the committee of judges was accepted.

The special committee on resolutions in honor of William Cain submitted a report (published together with a photograph of William Cain in the *Journal of the Elisha Mitchell Scientific Society* **46**: 121–122, 1931).

The special committee on resolutions in honor of John William Nowell submitted the following report for publication:

JOHN WILLIAM NOWELL, PH.D.[1]

Dr. John William Nowell passed away in a Raleigh hospital on November 25, 1930. The interment was the next day from the Wake Forest Baptist Church, of which he was a member and deacon. Since

[1] See Frontispiece.

1915 he had been a member of the North Carolina Academy of Science, and served on its Executive Committee in 1924, 1927, 1928 and 1929. In 1915 and again in 1918 he was chairman of the North Carolina Section of the American Chemical Society. The chemistry of the carbon compounds was the field of his special interest. His doctor's thesis was on the steric effect of ortho-substituted groups on parasulfamido benzoic acids.

Entering Wake Forest College from Hertford County, N. C., in 1899, he received the bachelor's degree in 1903. He returned as a graduate student in 1906 and in 1907 received the master's degree. The following year he was graduate assistant in the Wake Forest department of chemistry. The session of 1908–'09 he spent in graduate studies at Johns Hopkins University, but served the next session as Instructor in Chemistry at Wake Forest. He resumed his university studies at Johns Hopkins in the fall of 1910 and received there in 1912 his degree of Doctor of Philosophy. The two sessions following he was Instructor of Chemistry at the State College of Agriculture and Engineering. In 1914 he returned to Wake Forest College as Associate Professor of Chemistry, and on the resignation of Dr. Charles E. Brewer in 1915 Dr. Nowell was appointed to the full professorship of chemistry and remained head of that department until his death.

The intellectual ability and other personal traits of our departed associate won him universal respect and affection. His scholarship he put out to service in varied important activities beyond the walls of Lea Laboratory, and always with the quiet efficiency and friendliness which set him apart from our common clay.

WILLIAM LOUIS POTEAT, Wake Forest College,
R. N. WILSON, Duke University,
H. D. CROCKFORD, University of North Carolina.
Committee from the North Carolina Academy of Science.

The general resolutions committee rendered the following report:

"Whereas, two honored members of the North Carolina Academy of Science, William Cain and John William Nowell, have died during the past year, be it

"Resolved that we, the members of the Academy, express our regret, ask the secretary to extend our sympathy to their respective families,

and to send such families special notices of appreciation which have been prepared by appropriate committees."

E. M. MARTIN,
C. E. PRESTON,
A. S. PEARSE.

The above resolution was adopted by a rising vote.

The general resolutions committee then continued their report as follows:

2. "Resolved that the North Carolina Academy of Science express its appreciation to those in the North Carolina State College and Meredith College who have contributed so largely to the success of the thirtieth annual meeting by their courtesy, hospitality, and hard work."

E. M. MARTIN,
C. E. PRESTON,
A. S. PEARSE.

The above resolution was adopted by a rising vote.

Then followed a discussion as to whether it were in the field of the Academy to take notice of the plans for the observance of the two hundredth anniversary of the birth of George Washington, and finally, the Academy instructed its Secretary to transmit to the George Washington Bicentennial Commission the information that the North Carolina Academy of Science endorses the program of observance of the two hundredth anniversary of the birth of George Washington.

The nominating committee submitted the following nominations:

President—F. A. Wolf, Duke University.

Vice-president—W. E. Speas, Wake Forest College.

New member of the executive committee (for three years)—F. W. Sherwood, State College.

Academy representative to the American Association for the Advancement of Science (for two years)—H. R. Totten, University of North Carolina.

A vote was taken and the above officers and representative were elected.

C. F. Korstian, on behalf of the American Forestry Association and the North Carolina Forestry Association, called to the attention of the Academy their joint meeting scheduled to be held in Asheville, N. C., June 3, 4 and 5, and extended a most cordial invitation to the members of the Academy and their friends to attend and participate in the discussion on forest conservation.

The following committees for the coming year were appointed:

Committee on high school science: Bert Cunningham, chairman, H. B. Arbuckle, Lena Bullard, C. M. Heck, C. E. Preston, and R. N. Wilson.

Legislative Committee: Z. P. Metcalf, chairman, W. L. Poteat, and C. S. Brimley.

The business meeting then adjourned.

The departments of biology and chemistry of Meredith College were *At Home* to the ladies of the Academy from 4:30 to 6:00, Friday afternoon.

State College was host to the Academy at supper Friday evening with Z. P. Metcalf, a very genial toastmaster.

The Academy reconvened at 8:30 P.M., with Vice-president P. M. Ginnings presiding. B. F. Brown, Dean of the School of Science and Business, gave the address of welcome. Vice-president Ginnings responded for the Academy and presented President W. F. Prouty who then delivered his presidential address on "The Origin of Folded Mountains" (see page 33). The presidential address was illustrated with lantern slides.

After this a reception was given the Academy by the Academy members in State College.

The Academy convened in sections Saturday morning with President Prouty presiding over the general section; L. A. Bigelow over the chemists, H. D. Crockford, secretary; W. W. Elliott over the mathematicians, E. L. Mackie, secretary; and A. A. Dixon over the physicists, W. E. Speas, secretary.

The following group officers were elected by the group concerned for the year 1931–32.

North Carolina Section of the American Chemical Society—L. A. Bigelow of Duke University, chairman; F. W. Sherwood of State College, vice-chairman; H. D. Crockford of the University of North Carolina, secretary-treasurer; L. G. Willis of State College, councilor; A. S. Wheeler of the University of North Carolina (three years), R. W, Bost of the University of North Carolina (two years), and W. C. Vosburg of Duke University (one year), members of the executive committee.

Mathematics—E. T. Browne of the University of North Carolina, chairman; E. R. C. Miles of Duke University, secretary.

Physics—J. L. Lake of Wake Forest College, chairman; Calvin Warfield of the North Carolina College for Women, secretary.

The physics section voted to confine papers presented before that section in the 1932 meeting to ten minutes.

The following papers were presented. Those marked with * appear in full in this issue; those marked x are abstracted in this issue; for those unmarked no abstract was received; those marked † were presented by title only.

Corrosive Effects of North Carolina Soils on Culvert Materials. E. E. RANDOLPH and W. E. KOONCE, State.

A Note on the Influence on Nursing Rats of the Addition of Yeast to the Stock Ration. J. O. HALVERSON and F. W. SHERWOOD, State.

The Behavior of Kelp during Imbibition (Lantern). DONALD B. ANDERSON, State.

A Simple Dilatometer. CARLOS F. WILLIAMS, State.

A Summer's Experience with Grasses in North Carolina. H. L. BLOMQUIST, Duke.

Knob Formation on Sweet Potatoes Resulting from Soil Conditions (Lantern). R. F. POOLE, State.

Cultural and Innoculation Experiments with Taphrina Potentillae (Lantern). ELLA M. MARTIN, Greensboro College.

Effect of Calcium Deficiency on the Metabolism of Tomato Plants (Lantern). RUTH M. ADDOMS, Duke.

Narcissus Fire (Lantern). D. M. CREAGER, Duke.

x*Popular Scientific Language.* GEORGE W. LAY, Chapel Hill.

The Apparent Wet Spots which Appear Ahead when Travelling Highways. J. B. DERIEUX, State.

x*Air Breathing and Land Fishes of Siam* (Lantern). A. S. PEARSE, Duke.

**At What Hour is the Rainfall Heaviest?* LEE A. DENSON, U. S. Weather Bureau.

Types of Radio Reception (Opaque Projection). CHARLES M. HECK, State.

x*Pending Problems in Spectroscopy.* CHARLES W. EDWARDS, Duke.

Conjugation in Vorticella and Closterium. WILLIAM LOUIS POTEAT, W. F. C.

The Relation of Inorganic Salts to Growth and Reproduction in Amoeba proteus (Lantern). DONALD M. PACE, Duke.

Observations on Some Fungal Diseases of Algae (Lantern). J. N. COUCH, U. N. C.

x*The Chemical Composition of Ipomoea pandurata.* ELIZABETH M. STEPHENS and A. S. WHEELER, U. N. C.

Some Recent Trends in Science Teaching. F. H. EDMISTER, U. N. C.

**Nicholas Marcellus Hentz* (Lantern). COLLIER COBB, U. N. C.

x*Cataloging the Homoptera of the World.* Z. P. METCALF, State.

Some effects of Excessive Moisture on Peach Trees (Lantern). J. H. BEAUMONT, State.

Soil Water Relations in the Sand Hills. B. W. WELLS, State.

Some Activities of Micro-organisms in Sand Hill Soil. I. V. SHUNK, State.

Do Fertilizers Cause Corn to "Fire?" J. F. LUTZ, State.

x*Variations in Soils Derived from Sand in Eastern North Carolina.* W. B. COBB, State.

The $CaCO_3$ Content of Certain Beach Sands. G. R. MACCARTHY, U. N. C.

x†*The Probable Sedimentation of the Slates and Flint-like Slates of North Carolina* (Lantern). A. E. ALEXANDER, U. N. C.

Salt in the Triassic of North Carolina. JOSEPH HYDE PRATT and JASPER L. STUCKEY, State.

x†*The Influence of the Physiographic Features of Western North Carolina on the Settlement and Development.* MARTHA E. NORBURN, U. N. C.

**North Carolina's Singing Orthoptera.* B. B. FULTON, State.

**A Gynandromorph of Megachile latimanus Say* (Lantern). T. B. MITCHELL, State.

Notes on Lachnocladium and Clavaria. W. C. COKER, U. N. C.

Notes on the Seed Development of Pinus palustris (Long leaf pine) (Lantern). A. C. MATTHEWS, U. N. C.

Periodicity of Algae in North Carolina (Lantern). L. A. WHITFORD, State.

Comparison of the Flowering Dates at Chapel Hill, N. C. for 1930 and 1931. B. E. SMITH, U. N. C.

The Question of the Entrance of Common Tobacco Mosaic through the Roots of Tobacco Plants. S. G. LEHMAN, State.

x*Dune Sands and Wind-blown Soils of the Mississippi Basin* (Lantern). COLLIER COBB, U. N. C.

Studies in Nitrogen Fertilization of Peach Trees. CARLOS F. WILLIAMS, State.

Injuring of Sweet Potatoes Produced by Different Chemicals (Lantern). R. F. POOLE, State.

The Effect of Dusts on the Rate of Cuticular and Stomatal Transpiration (Lantern). DONALD B. ANDERSON, State.

†*Some Factors Involved in Resistivity Methods of Geophysical Explorations.* J. H. SWARTZ, U. N. C.

MATHEMATICS SECTION

A Poisson-Stieltjes Integral for the Heat Equation. E. R. C. MILES, Duke.

Our Expanding Universe. ARCHIBALD HENDERSON, U. N. C.

x*A Geometric Theory of Solutions of Linear Inequalities.* RUTH STOKES, Duke.

Differential Equations of Conformal Geometry. V. A. HOYLE, U. N. C.

Curves of Constant Curvature in a Function Space. J. A. GREENWOOD, Duke.

Some Properties of Dupin's Cyclide. E. A. CAMERON, U. N. C.

x*Pfaffian Systems of Equations.* J. M. THOMAS, Duke.

x*An Involution Associated with a Pencil of Conics.* J. W. LASLEY, JR., U. N. C.

x*A Problem of Average Value in Probability.* HENRY MONYER and E. R. C. MILES, Duke.

x*A Diagonal Property of Determinants.* E. R. C. MILES, Duke.

PHYSICS SECTION

Stresses in Wire Automobile Wheel. J. B. DERIEUX, State.

Red Fluorescence in Discharge Tubes. W. E. SPEAS and J. E. MORGAN, W. F. C.

The Variation of the Intensity of Fluorescence with Concentration in Liquid and Solid Solutions (Lantern). A. A. DIXON, State.

x*Electrodeless Discharge Characteristics of Hydrogen and Nitrogen* (Lantern). HENRY ZURBURG and OTTO STUHLMAN, JR., U. N. C.

x*The Structure Sensitiveness of Magnetism in Metals* (Lantern). F. W. CONSTANT and T. E. LOWANCE, Duke.

Electrical Resistance of the Human Body (Opaque Projection). KARL H. FUSSLER, U. N. C.

x*Variation of Inductance at Radio Frequencies* (Lantern). G. D. COLLINS, Duke.

The Continuous Band Spectra of Mercury Vapor. WALTER M. NEILSEN, Duke.

Effect of the Arc Length, and the Current Intensity, upon Wave-length of Some of the Spectral Lines of the Iron Arc (Lantern). E. J. BROWN and J. B. DERIEUX, State.

The Theory of Electrodeless Discharge at Low Pressures (Lantern). OTTO STUHLMAN, JR., U. N. C.

x*Evidence of Mosaic Crystals in Copper and Platinum* (Lantern). F. W. CONSTANT, Duke.

x*The Motion of Bursting Bubbles Rising through Liquids* (Lantern). C. J. CRAVEN and OTTO STUHLMAN, JR., U. N. C.

EXHIBITS

Regeneration of Diploid Gametophytes in Mosses. H. L. BLOMQUIST, Duke.

Narcissus "Fire" Specimens. D. B. CREAGER, Duke.

Apparatus for Measuring CO_2 Given off by Soils as an Index of Soil Fertility. I. V. SHUNK, State.

Differential Bacteriostasis of Crystal Violet on Gram Negative and Gram Positive Bacteria. I. V. SHUNK, State.

Complete List of Flowering Dates Recorded at Chapel Hill, N. C., January 1930 to May 8, 1931. B. E. SMITH, U. N. C.

Fishes. A. S. PEARSE, Duke.

Multi-tailed Lizard. BERT CUNNINGHAM, Duke.

Homoptera. Z. P. METCALF, State.

Some Economical Mounts for Winged Insects. T. B. MITCHELL, State.

North Carolina's Singing Orthoptera. B. B. FULTON, State.

Mutant Forms in the Parasitic Wasp, Habrobracon. C. H. BOSTIAN, State.

Dune Sands and Wind-blown Soils of the Mississippi Basin. COLLIER COBB, U. N. C.

Major Soil Types of North Carolina. W. B. COBB, State.

Photoelectric Cell. A. A. DIXON, State.

Radio Waves on Wires. R. E. L. GREENE, State.

Photographic Record of the Vegetation of North Carolina. B. W. WELLS, State.

Some of the Commercial Woods of North Carolina. Dept. of Forestry, State.

Fire-proof Wood. Dept. of Forestry, State.

How Strong is Wood? Dept. of Forestry, State.

How Fast do Trees Grow? Dept. of Forestry, State.

Cross-section of Femur Bone. C. F. DODSON, Campbell College.

Commercial Exhibits: Phipps and Bird, Richmond, Va.

Botany Greenhouse

An Inexpensive Electrical Transpirograph. DONALD B. ANDERSON, State.

A Simple Dilatometer. DONALD B. ANDERSON and CARLOS F. WILLIAMS, State.

NORTH CAROLINA SECTION OF THE AMERICAN CHEMICAL SOCIETY

The Chlorination of 1-5-Dihydroxynaphthalene. A. S. WHEELER and W. J. MATTOX, U. N. C.

Dipole Moments of Some Organic Halides. PAUL GROSS, Duke.

The Solubility of Oxalic Acid in Hydrochloric Acid Solutions. J. M. BELL and ETHEL M. CHAPIN, U. N. C.

The Partial Pressures of Some Organic Substances above their Aqueous Solution. J. H. SAYLOR, Duke.

Ternery Systems; Water, iso-Propanol, and Salts at 25°C. P. M. GINNINGS and ZOK TSUNG CHEN, G. C.

†*Action of Sulphur Dioxide on the Phosphates of Calcium.* F. K. CAMERON and A. E. HUGHES, U. N. C.

Cotton as a Source of alpha-Cellulose. F. K. CAMERON and N. W. DOCKERY, U. N. C.

Removal of traces of iron from Aqueous Solutions of Sulphates. F. K. CAMERON and T. W. RICHMOND, U. N. C.

The Estimation of Gossypol in Commercial Cotton Seed Meal. F. K. SMITH, State.

Some Reactions of Tin Tetratoyl. R. W. BOST and H. R. BAKER, U. N. C.

Further Studies of certain Ald-Chlorimines. C. R. HAUSER and A. G. GILLESPIE, Duke.

Sodium Alum. J. T. DOBBINS and R. M. BYRD, U. N. C.

The System: Lithium Sulphates, Aluminum Sulphate, Water. J. T. DOBBINS and J. P. SANDERS, U. N. C.

A Scheme for the Qualitative Separation of the Anions. J. T. DOBBINS and H. A. LJUNG, U. N. C.

Studies on Columbium and Tantalum. F. H. EDMISTER and G. G. ALBRITTON, U. N. C.

Laboratory Demonstration vs. Individual Laboratory Work. F. H. EDMISTER and J. L. LECONTE, U. N. C.

The following abstracts have been received:

Air-breathing and Land Fishes of Siam. A. S. PEARSE.

Observations on the gaseous content of the water in the shallow canals in which air-breathing fishes live indicate that there is often a lack of oxygen and a considerable amount of carbon dioxide. Lack of oxygen, as well as aridity, has doubtless been a factor in the production of air-breathing fishes. The gobies skip about on Siamese beaches in the intertidal zone, occupy the same areas but avoid interspecific competition by eating different foods. They have rather different species of parasites.

Popular Scientific Language. REV. GEORGE W. LAY.

Scientific writings are addressed to two different classes, and in each case the language used should be that which is best understood by those addressed. For a group of scientists exact technical terminology is appropriate and even necessary. But, when the writing is intended for popular use, the habit of using words and phrases unfamiliar to most people should be avoided, even though technical accuracy be partly sacrificed in order that one may be understood easily. Writings of the latter class should be revised by someone whose verbal capacity is no greater than that of the average man.

Pending Problems in Spectroscopy. CHARLES W. EDWARDS.

Investigation in the field of spectroscopy deals with two major projects: A complete knowledge of line spectra leads to an understanding of the structure of the atom; a complete knowledge of band spectra reveals the structure of the molecule.

Among the opportunities for research in the field of line spectra are: (1) The discovery and investigation of abnormal behavior of lines in intense electric and magnetic fields. Only a few lines have been investigated. (2) The discovery of new wave lengths in the spectra of ordinary elements and a more complete measurement of the wave lengths of the rare elements. (3) The study with better defined conditions and better equipment, the fine line and sub-fine line spectra. (4) The study of intensities of spectral lines and especially of the distribution of intensity within a single line. The width of lines needs investigation. A study of the relative intensities in multiple components will be of great interest. (5) There is still room for an investigation of the effect of gas pressure, nature of discharge, and other physical conditions of the

excitation of lines. (6) The study of reversal of lines is yet far from complete.

In the field of band spectra the work may well follow all of the lines indicated for line spectra. The study must be extended to cover the Schuman region, the optical spectrum and the visible region. A study of the spectra of almost any molecule will yield band spectra which are at present unknown. The fact that a dozen different band spectra have been measured for the CO molecule alone indicates the almost boundless opportunities in this field. There is reason for looking for sub-fine structure in band spectra. The study of isotopes through band spectra promises valuable results. A study of Raman spectra in in its relation to band spectra may establish an exact and determinable relation between spectra and the chemical behavior of substances and thus establish a new basis for chemistry.

The Chemical Composition of Ipomoea pandurata. MRS. ELIZABETH M. STEVENS and A. S. WHEELER.

Ipomoea pandurata belongs to the Morning Glory family. It occurs wild from Canada to Florida and west to Texas. The root sometimes reaches the size of a man's body, hence the popular name "Old Man of the Earth." Other members of the genus *Ipomoea* possess medicinal qualities, the resins present having a purgative action. After making qualitative tests on the dried powdered root, the constituents of the tuber were quantitatively determined. The results were as follows:

	%
Water	71.50
Invert Sugar	0.36
Sucrose	0.29
Starch	10.10
Cellulose and Ash	12.47
Resins	4.69

Cataloging the Homoptera of the World. Z. P. METCALF.

A brief discussion of systematic zoology with the place of nomenclature and its relation to systematics. It was pointed out that our concepts about the species, genera, and other groups can never be made to conform to rules. They will vary as new morphological characters are discovered. Names, however, can be made to conform to rules but, in spite of this fact, stability will never be attained because concepts are constantly changing. This, however, should not be used as an argument for not following the rules.

In Cataloging the Homoptera of the World, it was pointed out that the literature is widely scattered, comprising about forty-two hundred separate titles, located in about eight hundred separate works and about two thousand three hundred separate journals. It is estimated that the total number of genera named at the present time exceeds five thousand, the total number of the species exceeds thirty thousand and that the total number of references to genera and species will exceed two hundred and fifty thousand. This would require about fourteen volumes of five hundred pages each to complete the catalog. Detailed methods of making the catalog were discussed.

Variations in Soils Developed from Sands in Eastern North Carolina. WM. BATTLE COBB.

The sands of the coastal plain of North Carolina develop into several different soils, the variations in these soils being due largely to differences in drainage conditions and in degree of development.

The flat areas when first exposed above sea level are poorly-drained and remain so until further uplift and the development of drainage channels lowers the water table and permits aëration.

The Portsmouth sands are probably the first mineral soils to develop on the flat areas. These are dark gray to black sands underlain by gray sands. The Portsmouth sands may be modified by the formation of an organic hardpan at a depth around 20 inches. Such variations are called the St. Johns sands.

The Plummer sands are slightly better drained and are lighter in color than the Portsmouth sands. The Leon sands are the lighter colored hardpan soils. The hardpan of the Leon soils is more highly developed than that of the St. Johns soils.

As drainage conditions improve the Plummer sands probably develop into the Blanton sands which consist of gray upper layers underlain by nearly white sand which passes below into very pale yellow sand. The Leon soils may also develop into Blanton soils by the gradual disintegration and leaching out of the hardpan.

The St. Lucie sands are white sands with light gray surface layers. These were originally ridges or sand hills and probably become well-drained very soon after elevation above sea level and failed to develop Portsmouth and Plummer stages. These soils may develop into Blanton. They may also develop into Lakewood sands which differ from the Blanton in having a distinctly yellow third layer beneath a white second layer.

The Norfolk sands may develop from either the Blanton or Lakewood sands. These are the characteristic sands of the sandhills and of better drained areas in the coastal plain. They consist of a surface layer of gray sand underlain by light yellow sand.

If the percentage of fine material or iron-bearing minerals is sufficient the Norfolk sands may develop into the Ruston sands. The surface horizon of the Ruston sand consists of a grayish-brown sand. The Ruston sand probably represents the final well-developed soil from sands in the North Carolina coastal plain. It is probable, however, that many areas of Norfolk sand have reached their maximum development because of insufficient iron in the parent material to permit the formation of reddish colors.

The Probable Sedimentation of the Slates and Flint-like Slates of North Carolina. A. E. ALEXANDER.

A few words should be said about the work done by the older geologists to fully appreciate the complexity of the problem. In 1825, Denison Olmstead first called attention to the great slate formations in North Carolina. Later on Elisha Mitchell, Amos Eaton, Washington Kerr, Ebenezer Emmons, and George Williams added their contributions to the literature. Since their work is mainly of historic rather than of scientific interest, nothing further will be said about their work at this time. The first paper of importance appeared in 1895, when H. B. Nitze considered the slates or hornstones as probably devitrified rhyolites. He added that there was more than one volcanic outbreak, and that during at least one period of activity, the slates were deposited. Weed and Watson, in 1906 in a report on the slates of Virginia, which are a part of the Carolina slate belt, said that from petrographic, structural, and chemical evidence, the slates were derived from andesitic rocks. Two years later, Harry Eaton, in a paper published in the Elisha Mitchell Journal, remarked that the slates around Chapel Hill were derived from such acid volcanics as occur in great abundance in the vicinity. He also said the stratification and banding were not of sedimentary origin but mechanical, being due entirely to the arrangement of kaolin particles. In 1909, Francis B. Laney, in his doctoral thesis (Yale), concluded that the slates were probably sedimentary, the material being derived from volcanic flows, breccias, tuffs, ash, and possibly mud. He believes the series a sedimentary unit which represents a period of continuous deposition; the original variations in the material laid down depending upon the in-

tensity of the volcanic activity at that time. The following year Joseph Pogue, in a North Carolina survey report, states that the slates were derived chiefly from great masses of ejecta and so deposited in water with varying amounts of land waste and at no great distance from the source of the material. Nothing more was done until 1922 when James B. Miller, in his master's thesis (North Carolina), said that the sediments were deposited in deep seas, and that the apparent sandstones that are intercalated with the slates are not sandstones, but slates containing a high percentage of detrital quartz.

From the foregoing statements of the several geologists considered, it is very evident that a great difference of opinion exists as to the origin and the conditions under which the slates were laid down. In the light of new field evidence, let us consider a few things that characterize these metamorphics as being one time sedimentary rocks.

Throughout the series, banding is present; at one place it may be uniform, and again it may grade into coarser lenses, or be entirely absent. These sudden changes from coarse to fine material are indicative of shallow water deposition and not deep water deposition as several geologists have intimated in the past. The writer has several specimens in his collection that show very fine lensing, which are very characteristic of sediments that were deposited in a neritic environment, which is believed to have been estuarine; that is the arm of a Pre-cambrian sea. Edward M. Kindle, of the Canadian Geological Survey, and Jasper Stuckey, of North Carolina State College, are convinced that the slates represent shallow water deposition, and that they were probably estuarine.

In quoting Harry Eaton, it was brought out that he did not consider the banding in the slates to be of sedimentary origin, but due to the mineral arrangement of kaolin particles that took place prior to consolidation. The writer has still another specimen in his collection that shows seasonal banding, which heretofore has not been mentioned in the literature on Carolina slates. This particular specimen is again characteristic of shallow water deposition and of a distinct sedimentary series. R. W. Sayles, of the Harvard Museum, who has done much work on the Permo-carboniferous varves claims that the summer component is represented by layers of sand and silt, whereas the winter component is made up of clay. In the specimen in the author's collection, the light bands representing the summer component, and the darker bands the winter components, are very well brought out.

At this time it would be well to consider the analyses of the slates.

Very often an excess of sodium over potassium is noted. This, according to Jasper Stuckey, is pretty good evidence that the sedimentary materials, which for the most part are land wastes and some volcanic ejecta, were carried no great distance from their source and therefore are again indicative of shallow water deposition.

As we generally consider it, the average slate contains about 59 per cent silica. Many of the Carolina slates, especially those in the vicinity of Chapel Hill frequently run as high as 77% silica. The older geologists thought they were dealing with a rock that resembled the Arkansas novaculite, and named these slates "hornstones." Harry Eaton in 1908 referred to the Chapel Hill metamorphics as "Flint-like" slates, which for the time being is about as worthy a name as any yet given these rocks.

If we accept the slate series as a sedimentary unit, and the writer agrees with Francis B. Laney on this point, we must account for the great variation in silica content. No adequate explanation has however been advanced to-date. Let us consider what workers in other parts of this country have done on the slates that run high in silica, and attempt to apply their theories to the rocks in the Carolina slate belt. Rubey, in speaking of the Mowry (Cretaceous) shales of Dakota, which average 84% silica, believes in contemporaneous origin of the silica, and that the silica originally in the sea water might have come from river waters rich in silica, or from submarine springs, or from the solution of siliceous volcanic ash. He thinks that the precipitation of silica might have been brought about by silica secreting organisms, by electrolytes in the sea water, or by compounds derived from the decay of microscopic plants and animals.

Rae, on the other hand, believes the Mowry shales to be primary precipitation on the sea bottom of colloidal silica. Colloidal silica carries a negative charge and contact with positively charged ions brings about its flocculation into larger aggregates. The aggregates are in the form of gels which ultimately settle to the bottom where they are deposited with other sediments. Calcium, magnesium, sodium, and potassium in the sea are effective coagulating agents, according to Twenhofel.

At this point, I might say that it has been estimated that 11.6% of the matter carried in solution by rivers is silica, and according to Frank W. Clarke, over 319 million metric tons of silica are added to the sea annually.

It is quite possible that, in a neritic environment where sediments were being deposited in an arm of the sea, concentration and precipita-

tion of colloidal silica would take place. The most probable source of this silica seems to be local accumulations of land wastes derived from the acid volcanic rocks of the region. This precipitation would lead to the formation of a shale with an abnormally high silica content which would be quite different from the more normal sediments of the neighborhood. Such a shale might readily, through subsequent metamorphism, become altered to the slates and flint-like slates which we now find in the Carolina slate belt.

The Influence of the Physiographic Features of Western North Carolina on the Settlement and Development of the Region. MARTHA ELIZABETH NORBURN.

Of the three physiographic divisions of North Carolina, the coastal plain, the piedmont, and the mountain region, the mountain region has become the subject of especial geographic interest because of the unique type of civilization which has developed. The location of the Great Smoky Mountain National Park in the mountainous section of North Carolina and Tennessee has added to the interest.

The mountain region of North Carolina is the culminating portion of the Appalachian Mountain system. Bordered on the east by the old Blue Ridge escarpment and on the west by the younger and higher Great Smoky Mountains and its associated ranges, the area contains an intricate system of mountain ranges and intermontane valleys. Situated below the glaciated area, the region has no natural lakes, and owes its intricate detail of landscape features to the work of running water among highly tilted beds of unequal resistance. This work is particularly effective in the rainy Virginia climatic belt, Köppen's Cfa. The extreme age of the land, and the constant supply of moisture at varying elevations have had much to do in producing a flora rich in species and luxuriant in growth. The characteristic residual soil is the result of the weathering of the rock in a region constantly acted on by rain water.

The settlement and development are primarily dependent on physiographic features. By the decree of 1763, George II made the escarpment of the Blue Ridge the limit of settlement. In the eighteenth century, when the streams of population flowed into the piedmont from the reservoirs on the north and on the south, the northern stream was deflected from the mountains by the divide south of New River, the southern by the curving wall of the Blue Ridge. Those who ventured into what is now the state of Tennessee came down the troughs of the

Great Valley from Virginia. But neither royal decree nor mountain barrier could prevent the individual pioneer from braving the mountain passes. The hunter, the trader, and the surveyor led the way. The settler followed. It is significant that the first organized settlement beyond the mountain wall was initiated by the Watauga settlers, and had, as its purpose, order and defense. This settlement formed the first representative government on American soil. The people who settled the mountains were from mountain loving European nations. The independent spirit of the pioneer and his old world habits and customs became crystallized in his inacessible home. The later cosmopolitan development of the region has been brought about by the building of roads and the development of the resources of the region.

Dune Sands and Wind-blown Soils of the Mississippi Basin. COLLIER COBB.

The striking feature of such soils, whether they are derived from rock flour ground by the glacier, or produced by alternations of heat and cold from day to night in regions of little rain, is that the mineral components of the soils have suffered little, if any, chemical decay, their minerals being recognized by the microscope.

These constitute the best wheat lands the world over; but along the length of the Mississippi and most of its tributaries they are now used for extensive truck farming, or are devoted to dairying industries.

A geometric theory of solution of linear inequalities. MISS RUTH W. STOKES.

The author develops a theory of systems $\xi^{i} \geq 0$, where the ξ's are linear homogeneous expressions in n unknowns. Each condition is represented in n-dimensional euclidean space by the point which has for coordinates the known coefficients of the corresponding form ξ. A solution is accordingly an oriented $(n-1)$-flat which does not separate any pair of the points representing the given conditions. The paper determines the general solution of the following problem: find a solution of $\xi \geq 0$ which contains all points in a subset A of the given representative points and which contains no point in a second subset B. A general solution is thus obtained for any system composed of a finite number of conditions from each of the three types (1) $\xi \geq 0$, (2) $\xi > 0$, (3) $\xi = 0$. Such a system includes as special cases the system composed solely of conditions of type (1) studied by Minkowski (*Geometrie de Zahlen*, pp. 40–45); that composed solely of conditions of type (2)

studied by Dines (Annals of Mathematics, vol. 20, pp. 191–199); and that composed solely of conditions of type (3), which is a system of linear homogeneous equations. The method is geometric throughout.

Pfaffian Systems of Equations. J. M. THOMAS.

This paper deals primarily with systems of class five comprising two equations. It begins an enumeration of such systems which are reducible to a canonical form (a, b) whose equations are in the canonical form for a single equation of class a and b respectively. It is shown that no system of the type considered is equivalent to a system (1, b); that systems reducible to (3, 3) and to (3, 5) exist and that all systems so reducible are equivalent to the particular system (3, 3) considered by Goursat, *Problème de Pfaff*, p. 316; that systems equivalent to (5, 5) and not equivalent to (3, 3) exist. As by-products of the investigation are obtained a method of finding the integrable combinations of any Pfaffian system, and a process giving definite information about the minimum number of differentials which enter into any system equivalent to a given system.

An Involution Associated with a Pencil of Conics. J. W. LASLEY, JR.

There is associated with an ordinary point of a curve a pencil of penosculating conics obtained in the following way. Consider the pencil of conics determined by the point in question and three additional points on the curve. As the three points approach the fourth the pencil of conics approach the pencil of penosculating conics. Among these conics Wilczynski found one, and only one, parabola, the osculating parabola. There is a unique equilateral hyperbola, the object of study by Cesaro. Wilczynski found also an ellipse of minimum eccentricity. The study reported on in this paper has to do with a certain involution associated with these conics. Those ellipses of the pencil are paired which have equal eccentricity; those hyperbolas are paired which for a given suitable eccentricity have that value, one for its real foci and directrices, the other for its imaginary foci and directrices. There turns out to be no hyperbola of maximum eccentricity. The partner of the osculating parabola proves to be the twice counted tangent at the original point. The osculating equilateral hyperbola and the ellipse of minimum eccentricity are found to be the double conics in this involution of penosculating conics.

A Problem of Average Value in Probability. E. R. C. MILES and H. W. MONYER.

There are n balls in an urn numbered from 1 to n. What is the average number of trials necessary to pick K different numbers?

The solution is shown to be a harmonic series of K terms and an approximate value for this series is proposed. The series is shown to be equivalent, as an approximate value, to a logarithic term. The limit of error of the approximation is demonstrated.

A Diagonal Property of Determinants. E. R. C. MILES.

Montmort's example, a classical theorem in finite probability, is shown to be equivalent to a theorem which gives the number of terms of a determinant which do not contain an element of a given diagonal. Another problem in combinations is proposed, the solution of which yields a theorem relative to the number of terms of a determinant which are free of elements of two of its diagonals.

Electrodeless Discharge Characteristics of Hydrogen and Nitrogen. HENRY ZURBURG and OTTO STUHLMAN, JR.

Electrodeless arc discharges were obtained by means of a predominant electrostatic field in a spherical bulb placed in a long solenoid excited by undamped high frequency oscillations Critical minimum potentials to strike the arc were obtained as a function of gas pressure for frequencies between 1.5 and 4.5 million cycles. The characteristics conformed closely to Pashan's law. The critical points defined by the minimum values of X_m and P_m for a given frequency of excitation showed that the Log $(X/p)_m$ was a linear function of the frequency f, between discontinuities, interpreted as critical points of ionization. These critical ionization points were found to be interpretable as arising through successive impacts. The results show that here as in Townsend's work at higher pressures X/p increases with decreases in p. X_m was found to decrease with increase in f except where the relation passed periodically through sharp maxima, indicating by their shapes differences in elasticity of impact between the two gases, nitrogen behaving like an inelastic gas and hydrogen like an elastic gas. Pressure frequency relations indicated the existence of the same ionization discontinuities.

The Structure Sensitiveness of Magnetism in Metals. F. W. CONSTANT and F. E. LOWANCE.

The changes in magnetic susceptibility of copper, silver, bismuth and platinum, when subjected to various degrees of cold work, have been determined by means of the Gouy method. The specimens were in the form of 2 mm. wires, and were of a high degree of purity. They were passed through various stages of twisting, stretching, (up to the breaking point), and pounding, and the susceptibility determined at each stage. Results indicate a decrease in the diamagnetism for the diamagnetic metals, and in the case of platinum an increase in the paramagnetism. Graphs of this change show an approach to saturation with increasing cold work. This is considered as being caused by an increase in the paramagnetic component of the magnetism, which is due to the free electrons.

Variation of Inductance at Radio Frequencies. G. D. COLLINS.

An investigation of the change in inductance with the pitch of winding is being carried on, the frequency range being from 1000 to 3000 kilocycles. Five coils were wound on separate bakelite forms 3.5 inches in diameter, the wire being No. 22 d.c.c. solid wire, and the spacing varying from close winding to 0.764 turns per centimeter. There were 13 turns on each form and the inductance varied from 24.85 to 28.00 microhenries in the case of the closely wound coil, and from 9.78 to 10.08 for the coil of widest spacing. The distributed capacitance of the coils was found to be rather high. The present paper is in the nature of a preliminary report, as it is hoped to extend the investigation to coils of other types and to obtain more quantitative results.

Evidence of Mosaic Crystals in Copper and Platinum. F. W. CONSTANT.

Small pieces of copper were annealed in a vacuum for three hours at 1000°C. and two or three large single crystals obtained. These were ground, polished and etched with nitric acid and photomicrographs taken. By the etching, and also by straining, regularly spaced planes were brought out, believed to coincide with the pi-planes of F. Zwicky's theory of mosaic crystals. This mosaic structure was also observed in polycrystalline platinum, annealed at 1500° and similarly polished and etched. The secondary structure has different directions for each individual crystal of the polycrystal and the spacing of the lines representing the pi-planes is a minimum when the section is taken normal to this set of planes. This distance measured 1.2×10^{-4} cm. for both metals.

The Motion of Bursting Bubbles Rising through Liquids. C. J. CRAVEN and OTTO STUHLMAN, JR.

Small bubbles of gas rising through a liquid at various depths, great compared to their dimensions, arrive along a spiral path, at the surface with the same terminal velocity. They roll under the surface film, come to rest and burst, projecting fragments of liquid into the air. These fragments rise to different heights. For a given radius of bubble, temperature remaining constant, the separate fragments follow a near Maxwellian distribution, when distribution in height is examined as a function of diameter of bubble. After the maximum height is passed the above distribution becomes less regular, probably due to distortion in shape of the larger bubbles. Bubbles rising through water at 21°C. having diameters up to 0.16 cm. burst into three fragments, from 0.16 to 0.20 cm. they burst into two fragments. Bubbles larger than this burst irregularly.

H. R. TOTTEN, Secretary

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY

October 14th, 1930, to May 12th 1931

322nd Meeting, October 14, 1930

H. V. Wilson: *The larval metamorphosis in monaxonid sponges.*

In a study of the metamorphosis of the monaxonid sponge larva carried on at the Naples Zoological Station during 1929–30, attention was concentrated on *Mycale* (*Esperia*, *Esperella*) *lorenzi*. The so-called inversion of the layers was found to be true. Certain mesenchyme cells break through the surface epithelium of the larva and become the permanent epidermis, the epithelium cells passing into the interior and becoming the collar cells. The cell behavior leading to this result is still under investigation. Delage's account of the engulfing of the epithelium cells by amoebocytes with their subsequent liberation rests, it is thought, on an erroneous interpretation of the phagocytosis of degenerating cells.

Collier Cobb: *Light on the Loess Problem from the Mississippi Valley.* (By title.)

323rd Meeting, November 11, 1930

T. F. Hickerson: *Stress Analysis by Mechanical Methods.* (Demonstrated.)

An apparatus measuring the deformations of elastic models of structures or machines was exhibited. This device, invented by Professor George E. Beggs of Princeton University, consists of gages, gage plugs and micrometer microscopes which furnish a precise means for measuring small displacements and deflections of the model. This information enables one to determine the relation between loads and reactions on the actual structure however complex or unsymmetrical it may be.

A small celluloid model of a 160 foot concrete arch bridge constructed by the Georgia Highway Commission in 1927 was shown; and a determination of the thrust, shear and bending moment in the arch caused by a load was demonstrated with the aid of the Beggs Deformeter. A

comparison with results obtained by means of a mathematical analysis of this arch showed a remarkably close agreement.

It was stated that although the model is usually cut from a sheet of celluloid, the results obtained apply to material of any kind in the actual structure.

W. C. COKER: *Some Interesting Early American Naturalists.*

324TH MEETING, DECEMBER 9, 1930

A. S. WHEELER: *The Bromination of 1,5-Dihydroxynaphthalene.*

(A) Compound A dissolved in acetic acid yields with bromine a dibromo substitution product (B), colorless needless. Diacetate, yellow needles. Dimethyl ether microscopic plates. Diethyl ether, needles Dibenzoate, needles. Compound B treated with chromic acid gave a dihydroxy-dibromo-naphtho-quinone (C), rich red needles. Acetate, golden yellow needles. Reduction of C with zinc dust gave a dibromo trihydroxy naphthalene, colorless needles. C also gave an anilino derivative, needles with a gun metal luster.

By using more bromine A yields a tribromo compound (K), cottony crystals. Diacetate, needles. Dibenzoate, microscopic plates. Dimethyl ether, needles. Diethyl ether, needles. Oxidation of K with chromic acid gave a quinone, red needles. L yielded a monoacetate, golden brown scales.

If the acetyl derivative of A is dissolved in chloroform containing a little iodine the addition of six moles of bromine gave a tetra-bromo derivative (S). Dimethyl ether, needles. Dibenzoate, irregular plates. Compound S oxidizes to the tribromo quinone L described above. L yields an anilino derivative, dark red needles with a green fluorescence. Reduction of L gave tribromo trihydroxy derivative, silky needles. Triacetate, fluffy needles. Pyroboroacetate gave a phroboro-acetate ester (BB), hexagonal plates with a green luster, unstable in the air.

Five moles of bromine converted the diacetate of A into two products: (W), a dibromomonoacetate, needles and (S). Benzoylation of W gave a monoacetoxy-monobenxoxy derivative, rectangular plates.

K. H. FUSSLER: *The Electrical Resistance of the Human Body.*

The method used was a four-point-contact method using a Leeds and Northrup type K potentiometer. Measurements were made of the direct current passed through the portion of the body under investigation and the differences of potential simultaneously produced. Previous

investigators have failed to eliminate the large contact resistances and have reported results far in excess of the actual body resistance.

The resistances of various individuals range from 262 to 543 ohms when measured from hand to hand, but is constant for a given individual during a set of measurements. The resistance of a given individual varies slightly from day to day. From foot to foot the results are 209 to 400 ohms and for the trunk −18.4 to 28.2 ohms.

The resistance does not vary with the voltage, current, time of current flow and electrolyte used to make contacts. It is affected by flexing the muscles, position of the body and anger.

325TH MEETING, JANUARY 13, 1931

J. F. DASHIELL: *A Forward Going Tendency in Maze Running.*

(1) In multiple-U mazes white rats were found to run the true path more easily when the blinds were located always on the same constant side (C) than when they were located alternately right and left (A). This phenomenon was examined by variations of mazes in several series of experiments. (2) When additional segments were added to the multiple-U mazes the animals manifested a tendency to run in the C manner regardless of which way they had been trained in the original mazes. (3) When the C and A mazes were built on scales both smaller and larger no alteration was found in the fact of easier running in the former. (4) Motion picture analyses brought out little if any evidence for any maintenance of gross orientation from turn to turn. (5) Simple mazes consisting of a straightaway, an elbow, and a T-choice with one alley running forward and one backward, when used with untrained rats brought out some indication of a tendency to choose the former type of alley.

Different hypothetical explanations of the greater easiness of the C type maze are canvassed. It seems likely that the factor most responsible is a forward-going tendency in animal locomotion that leads not only to maintenance for short distances of a direction already set but also to a compensatory sort of correction when forced out of line by an obstruction.

O. STUHLMAN: *A Thermionic Megger with Linear Scale.*

326TH MEETING, FEBRUARY 10, 1931

N. P. BAILEY: *Response of Thermocouples to Rapidly Oscillating Temperatures.*

F. K. CAMERON: *Absorption of Sulphur Dioxide by Calcium Phosphates.*

Vapor pressure measurements have been made of mixtures of water, sulphur dioxide and calcium phosphates between zero and 90°C. Between 25° and 100°C. under pressures from 3 to 10 atmospheres, calcium phosphate may be completely dissolved by an aqueous solution saturated with sulphur dioxide. Phosphoric acid goes into solution more rapidly than the lime. But at equilibrium the lime is in excess. With ground phosphate rock, all the phosphoric acid may be made available by this method.

Dry treatment of the rock with gaseous sulphur dioxide at high temperatures involves complex reactions, with much decomposition of sulphur dioxide and liberation of elemental sulphur. About two-thirds of the phosphoric acid is thus made available.

Good recoveries of available phosphoric acid are obtainable with sulphur dioxide, but with no promise of economy over standard practice with sulphuric acid.

327TH MEETING, MARCH 10, 1931

G. R. MACCARTHY: *Beach Sands.*

Sieve analyses of beach sands collected from the Atlantic coast indicate that:

1. There is a strong tendency for the sands to move southward along relatively straight segments of the coast.
2. The gradual diminution in average grain size is, when measured as "average fineness," a linear function of the distance traveled.
3. There is strong evidence in support of the idea that near openings in the coast line, i.e., estuaries, inlets, etc., the effective direction of shore drift is toward the inlet even if this reverses the region drift.
4. In many cases evidence was obtained that a portion of the sand was of local origin, while another portion of it had been drifted in from farther north.

J. N. COUCH: *Some Biological Associations Between Insects and Microorganisms.*

328TH MEETING, APRIL 14, 1931

H. A. LJUNG: *A System of Qualitative Analysis for the Anions.*

A systematic scheme of analysis for the separation and identification of the anions has been developed. This scheme uses as its basis the theories concerning the mechanism of amphoterism and oxidation and reduction reactions, which stress the influence of the hydrogen ion con-

centration on reactions of this type. By controlling the hydrogen ion concentration of the containing solutions, the interferences commonly met in the anion analysis have been eliminated to a very great extent, thus making it possible to separate and identify practically all of the common anions without undue interference. There are a few cases wherein interference has not been completely overcome. Only in the case of the ferricyanide has a complete disappearance of the ion been detected.

The anions have been classified into groups according to their behavior with certain metallic ions. The ions composing the various groups are then separated and identified by special tests.

Group I

To this group belong the following ions: carbonate, fluoride, oxalate, sulfite, arsenate, arsenite, phosphate, and tartrate. These ions are precipitated as the *calcium* salts from alkaline solution.

Group II

To this group belong the following ions: sulfate and chromate. These ions are precipitated as the *barium* salts from alkaline solution.

Group III

To this group belong the following ions: cyanide, borate, ferricyanide, sulfide, and ferro cyanide. These ions are precipitated as the *zinc* salts from alkaline solution.

Group IV

To this group belong the following ions: thiosulfate, thiocyanate, iodide, bromide, and chloride. These ions are precipitatd as the *silver* salts from solution slightly acid with respect to nitric acid, with the exception of the thiosulfate which is transformed into silver sulfide.

Group V

To this group belong the following ions: chlorate, nitrite, and acetate. These ions are not precipitated but are identified in the filtrate from Group IV.

Group VI

To this group belongs the nitrate ion. Nitrate is identified on some of the original solution.

The applicability of this scheme has been shown by numerous test analyses and by the determination of the sensitivity of the test for each

ion, both alone and in the presence of large amounts of other ions. Analyses have also been made to test the effectiveness of the sodium carbonate decomposition of insoluble salts.

W. C. GEORGE: *Some Significant Examples of Rhythm in Organisms.*

Numerous correlations are known to exist between various cosmic forces and cycles of metabolism in organisms. Examples were cited to illustrate the coincidence between metabolic rhythms and (a) the rotation of the earth on its axis, (b) the revolution of the earth in its orbit, (c) the revolution of the moon, and (d) sunspot cycles.

329TH MEETING, MAY 12, 1931

A. HENDERSON: *The Expanding Universe.*

J. M. VALENTINE: *Blind Cave Beetles.*

The American *Trechinae* of the family *Carabidae* (ground beetles) has been selected to furnish material for a monograph which is intended to be a study in adaptation to circumscribed environmental conditions. The *Trechinae* nicely fulfil this requirement since they are normally restricted to the inner recesses of limestone caverns.

A recent trip to the southern Appalachian limestone system in which seventeen caves were explored, has revealed the fact that the group extends its range over an area vastly larger than the previous records of collectors would indicate. Eleven new forms representing the general *Pseudanophthalmus* and *Neaphaenops* strongly augment the evidence that the extent of interspecific difference in anophthalmids can be correlated with the remoteness of isolation achieved by subterranean migration and geologic change.

Evidence was put forward in defense of the theory of orthogenesis, or directive evolution. It was emphasized that internal factors operating to vary organisms should be viewed as correlation with external or environmental factors, not as random forces productive of mutations which owe their survival solely to the selective action of the environment; evidence was cited to the effect that natural selection is little more than of secondary importance in orthogenesis, or even in many cases of drastic mutation.

In conclusion, it was pointed out that the adaptive characters in anophthalmid beetles are probably the results of long and gradual orthogenic change, but that the interspecific characters of relatively recent origin represent the beginnings of secondary lines of evolution in which the characters apparently partake of the nature of fortuitous mutations.

ORIGIN OF FOLDED MOUNTAINS[1]

By W. F. Prouty

I have chosen the origin of folded mountains as a subject for discussion for the reason that these great earth structures are of interest to all of us, and because the theories of their origin are many and widely divergent. For most of us the mountains are a great source of inspiration and pleasure. Whether we see them from afar or near at hand, there is always something about them that holds our attention. We see in them the ever active forces of nature; the rushing stream, the avalanche, the massive glacier, the jagged peak, the lightning flash, the ever shifting clouds. From the earliest time man has opposed his strength to the mountain mass and frequently he has lost.

Much of the history of the earth is written in the mountain rocks and their structure. Man has learned much from this source but he has yet much more to learn. Leonardo da Vinci, the great artist, architect and scientist, was convinced that the fossils in the rocks of the high Alps were once sea shells. We know now that he was right, that these shells were buried in the sands, clay and ooze of the sea bottom and later were elevated to their present position. Not only were these sediments lifted but they were folded, buckled, sliced and mashed; in places greatly altered and injected by igneous rock, so that the present mountain mass is a great structural complex. Some mountains are less intricate in their structure than the Alps, but others are even more complex.

From the study of mountains we get many facts. We find that there are many active, unbalanced forces in the earth. The elevation of the Colorado Plateau from *below* sea-level to more than eight thousand feet *above* sea-level, shows a tremendous, persistent and wide-spread, vertical force. The rise and fall of many parts of the coast line of Italy, in historic time, is a good example of the less constant, vertical forces. The folding, mashing, slicing and shearing of the rocks in many of the mountains is ample proof of the lateral compressional forces in the

[1] Presidential address delivered before the North Carolina Academy of Science, May 8, 1931.

earth's crust. Tensional forces, elsewhere, have pulled the rocks apart, allowing great wedge-shaped blocks to sink into trough-like areas, as that of the Great Basin, the Rhine Valley and our own Triassic structural basin between Chapel Hill and Raleigh. By the use of the pendulum man is able to measure the relative mass of the various earth segments. It is found that the mountain masses are made of material lighter than the average of the earth's crust, and observations show that wherever the earth is receiving a load it tends to sink, as at present in the Mississippi Delta Region, or in northern United States during the ice invasion; also where load is being removed the earth's surface rises, as in many mountain areas losing weight by erosion, or as in Northern United States, after the retreat of the great ice sheet. These compensating movements are very slow and have a considerable lag. Following the retreat of the ice sheet the Lake Champlain Region, for example, was buried at first several hundred feet beneath sea-water. Compensating forces (isostasy) have but recently finished returning this area to its normal elevation.

A study of the earth's mountains shows:

1. Mountains have generally been formed along the border of the land mass which furnished the sediments now found in them (The sediments in the Appalachian Mountains came from a great land mass, Appalachia, now occupied by the combined Piedmont, Atlantic Coastal Plain and the Continental Shelf)

2. Young mountains are usually nearer the present border of the continent than the older mountains. (In western North America the Coast Ranges are younger than the Sierras or the Rockies.)

3. All older mountains, which have been deeply eroded, show a core of igneous or metamorphic rock.

4. Youthful, growing mountains are usually earthquake and volcanic zones, as witness the borderlands of the Pacific and Mediterranean Areas.

5. Growing coastal mountains usually have great ocean deeps in front of them, the so-called ocean fore-deeps, as for example the six different fore-deeps west of the Andes, the Supan fore-deep of the Aleutian Islands and the Tuscarora fore-deep of the young mountain range of the Japanese Islands.

6. Mountain making is going on seemingly with as great force as ever in the earth's history. All about the Pacific, lands are being elevated, and, in many places, the ocean fore-deeps are sinking, frequently with sudden slips and violent earthquakes.

7. Mountain making accompanied by great continental emergence, has brought to a close each of the great geological eras.

8. Many of the great mountains are curved or arcuate in character. All the present-day, growing mountain-arcs, as the Aleutian Arc, the Kurile Arc and the Japanese Arc, have their convex side toward the ocean fore-deep.

9. Most folded mountains have thrust faults and unsymmetrical folds.

10. All old mountains have been worn down and most of them have been re-elevated, some, many times.

One of the questions most frequently asked is in regard to the origin of these earth highlands. Before we attempt to answer this question we must understand that mountains are of different origins. We have mountain peaks of the type of Vesuvius or Shasta, which have been built up from the earth's surface by volcanic ash and lava flow. Others like the Hawaiian Islands have been built up by a succession of lava flows from the ocean floor, in this case to a height of over thirty thousand feet.

We have mountains made of great blocks of the earth's crust, faulted and tilted on edge, and raised relatively above the blocks which have been down-faulted. The High Sierras, the Wasatch and many of the mountains in the Great Basin Area, are examples of these so-called "block mountains."

We have the so-called "laccolithic mountains" which have been formed by the injection of great masses of igneous rock into the earths' crust, and the arching of the earth's surface above such injected masses, as for example the Henry Mountains of Utah or the Crazy Mountains of Montana.

All elevated land masses are being constantly reduced by the agents of erosion, chiefly running water and glaciers. The least eroded portion of such elevated land masses, irrespective of cause of elevation, are left as so-called "erosional mountains," as Mount Mitchell, Monadnock, and the Matterhorn.

The most general type of mountain, however, is the one which is made up mostly of folded rock. All the great mountain ranges of the world belong to this type, though they may be locally modified by injection, faulting or erosion, into other types.

The origin of these great folded mountains has engaged the attention of many men of science. Strong differences of opinion have led to controversies and these in turn have led to detailed studies of "Mother

Earth." This study has been carried on by men of various sciences, but chiefly geology, physics, mathematics and astronomy. The field is too broad to be mastered by any one group of scientists.

Before we undertake to discuss the origin of folded mountains let us review briefly some of the known facts and current opinions concerning the nature of the earth's interior:

1. Under the influence of tidal forces the earth is at present as rigid as glass or as steel, therefore largely a solid.

2. The density of the surface rock is about 2.7, while the density of the earth as a whole is about 5.52. This means that the density of the core is necessarily very high. Both the density and the character of the earth's interior have been computed from the behavior of the different earthquake waves in their passage through the earth, and as recorded on seismographs in many parts of the world.

3. It is the general opinion of scientists that the outer crest of the earth is a highly siliceous material, largely granitic in character, extending to a depth of 35 to 40 miles in the continental areas. Under the shallow ocean basins it extends less deeply and is probably entirely absent in the deeper portion of the Pacific. Below the granitic layer and reaching to a depth of about 1000 miles, is basic igneous rock. This basic division increases in density with depth and reaches at base a density of about 4.5. The upper part of this division is basalt and the lower part is peridotite. The basal portion has in general, at the present time, a crystalline upper layer, which is thicker under the ocean, where heat escapes more rapidly than under the continents. Beneath this crystalline layer the basalt is thought to be in a glassy, highly heated, solid-fluid condition.

From 1000 miles to 1800 miles there seems to be a gradual transition from peridotite to nickel-iron, with density increase from 4.5 to 9.

From 1800 miles to the center of the earth, at 3980 miles, the material is thought to be largely nickel-iron of a non-elastic character and possibly fluid, since transverse earth waves do not pass through it. At the center of the earth the density is estimated to be about 11.6. At the surface of the earth an equal mixture of iron and nickel would have a density of about 8.3.

4. The temperature in the crust of the earth, as recorded in deep borings, shafts and tunnels, shows an increase with depth at the rate of about 1 degree farenheit for each 60 to 70 feet. If this rate of increase continues with depth, which is improbable, the center of the earth would have a temperature of about 350,000 degrees farenheit.

5. The outer portion of the earth is a poor conductor of heat, thus the surface temperatures are mostly controlled by the sun's heat. The amount of heat radiated into space by the earth is greatly increased by the close approach of the molten rock to the earth's surface or during periods of vulcanism.

6. Radioactive materials in the earth occur in all types of rock but more largely in the acid or granitic types. It is thought by many that sufficient heat is derived from the slow decomposition of radioactive minerals to periodically melt a considerable portion of the basaltic layer, and locally the lower part of the siliceous crust.

7. At the earth's center there must be a pressure of about 45,000,000 pounds or 22,000 tons per square inch. Under this heavy pressure all substances would be considerably reduced in volume, and it is not unlikely that there is in the earth a gradual molecular change of the lighter minerals into the heavier minerals, thus causing earth shrinkage. This molecular change is known to have occurred in the once more deeply buried portion of the visible crust. With release of pressure in surface layers of the earth, minerals tend to form with less density.

8. The amount of yielding of the earth in response to load is much too great to be explained by the elasticity of the rock. It can best be explained by the settling of the crystalline surface portion of the earth into the glassy, solid-fluid deeper portion, as a mass of soft, though elastic, bees-wax will hold its shape and settle into a much harder, though solid-fluid pitch. We may think of this deep-lying, glassy, solid-fluid mass as the ocean on which ride the more rigid and elastic, crystalline rock-ships of the continents. When heavy loading occurs, a ship sinks deep in the water, and when unloaded, it displaces less water and rises. The geologist speaks of this compensation for load as isostatic adjustment. The glassy basaltic layer is highly sensitive to sudden transverse earthquake waves, thus appearing as an elastic body, but at the same time it yields readily to small, slowly applied forces.

In discussing the origin of folded mountains we must bear in mind that a number of the above conclusions concerning the earth's interior are relatively new and not fully proven.

Since most folded mountains are near the borders of continents and since most of them are made up in large part of great thicknesses of sedimentary rock, deposited in shallow water, it is apparent that the mountains have developed where once there was a slowly sinking basin of marine sediments (a geosyncline). In most theories of origin, there-

fore, the geosyncline is the controlling factor of location. Any theory to explain folded mountains must, of course, meet all the conditions of location, extent, characters of folding, amount of earth shortening and sources of materials.

In considering present day theories let us confine ourselves to those most generally accepted.

SINKING GEOSYNCLINES

One of the older theories is the so-called geosynclincal theory, which holds that in regions of extensive sedimentation, usually along the border of continents, the slowly sinking geosynclines carry the unconsolidated and water-soaked sediments to great depths. These sediments become greatly heated by the ascending iso-geotherms. With the increase in temperature and probable partial fusion in depth, comes increase in volume, which finally more than offsets the slow sinking. This zone of highly heated and relatively weak sediments, having displaced the stronger rock by isostatic adjustment is in a condition to be readily folded by the lateral compression, exerted in the crustal portion of the earth, due to the shrinkage of the earth's interior, through loss of heat or otherwise.

In the early days of this theory, shrinking through loss of heat seemed ample to account for the known amount of lateral compression. In later time when larger horizontal movements were recognized, increasing earth density, through recrystallization, was added as another cause of radial earth shortening and compression. It has been apparent also that the wedge action of igneous masses, pushed up through the strata and forming great laccoliths in the strata, have been in some regions a added source of lateral compression. This theory is advanced by Arthur Keith of the U. S. Geological Survey in accounting for the great amount of lateral compression in the Appalachain Mountains. We find that wherever in the Piedmont we have great masses of late Paleozoic igneous rock we have also, to the northwest of these area, a marked bulge or salient in the Appalachian folds, as though the introduction of this igneous rock had pushed the folds to the northwest beyond their normal position. Such an igneous mass is to be found extending from Danville, Va., through Greensboro and Charlotte and on into South Carolina.

According to this geosynclinal theory all continental borders should show parallel mountain growths. While this is generally true, there are glaring exceptions. For the most part the Arctic and Atlantic Ocean

borders are relatively free from such parallel mountains. Along the border of these two ocean basins, mountains, where present, approach the shore at such angles as to suggest that they continue beyond the continental border. The Appalachians for example, pass into the Atlantic from Newfoundland as though they are headed straight for Great Britain.

In brief this geosynclinal theory explains the chief cause of zones of crustal weakness and supplies a few of the many possible reasons for crustal buckling. It leaves unexplained many facts connected with folded mountains.

CONTINENTAL DRIFT THEORY

The second theory to be considered is the so-called continental drift theory. It is one of the younger and more spectacular theories, which has a strong appeal to the imagination. If true, it would explain in a simple way many perplexing facts formerly explained in various ways. This fact alone has brought it many defendants.

According to this theory, in late Mesozoic time, all the now separated continents formed one great continent, Pangaea, in the Greater Pacific Ocean. Due to unusual tidal and centrifugal forces, not successfully explained, this great unit mass broke up into the present continents which drifted westward and equatorward, Africa remaining relatively fixed in its present position. To account for the peculiarities of drift and the position of climatic zones, the position of the pole of the earth must be shifted through many degrees. According to this theory the folded mountains were formed by the buckling of the sea sediments and sub-ocean crust in front of the continental ship slowly plowing through the solid-fluid sub-crust.

This theory is substantiated by the more or less perfect fit of the continents when restored to their theoretical former positions. The close fit of South America and Africa is obvious. The other continental masses do not fit so well. Greenland and North America were supposedly in contact with the west coast of Europe and the northwest coast of Africa. The west coast of India fitted along the east coast of Africa to the north of Madagascar. Antarctica and Australia together overlapped the southeast coasts of South America, Africa and India.

Professor Taylor[2] of the United States and Professor Wegener[3] of

[2] See references at end of article.
[3] See references at end of article.

Austria are the principal advocates of the Continental Drift Theory. Professor Taylor emphasizes the equatorward (centrifugal) forces while Professor Wegener emphasizes the westward (tidal and precessional) forces.

The theory of Continental Drift explains the lack of coastal mountains on the Atlantic and Arctic borders and the apparent break of continuity of certain east-west mountains, as between North America and Europe, northern South America and the Mediterranean Region, Argentine and South Africa. This theory might also, according to R. A. Daly, "make plausible Plato's account of the lost Atlantis, off the Pillars of Hercules." The mid Atlantic ridge is thought to represent a parallel strip of land left behind in the continental migration and, later on, modified by vulcanism along the rift zone.

Against these major appearances and minor facts, in support of the theory, we find an equal or larger number of facts diametrically opposed to it. There is, for instance, insufficient space in the Arctic Ocean to account for the assumed southward migration of Asia and the westward migration of North America. The shifting of the poles could not have occurred as conjectured, because of the fact that large glacial areas are known to have existed in the postulated tropics. Further, without polar shift, the theory does not account for the present position of Australia and Antarctica. When detailed structure and rock character of the corresponding coastlines of South America and Africa are examined, they do not show the expected relationship. It is further objected that we do not know of an adequate force for moving the continents over a solid-fluid sub-crust.

While the theory accounts for the formation of the Tertiary mountains of the Pacific and the Mediterranean, and also accounts for the lack of mountains bordering the Arctic and the Atlantic, it falls down in its explanation of so many other facts, that we must reserve judgment as to its merits and accept it at present only as a brilliant attempt to give a general explanation for many scientific facts.

GRAVITATIONAL SLIDING OF CONTINENTS

Some years ago Eduard Suess put forward the idea in his epoch making book, Das Antlitz der Erde, that the mountains of southern and eastern Asia have resulted from the slow creep or gravitational sliding of the great continental mass of Asia, towards the bordering deep Pacific Basin. It was in part from this suggestion that F. B. Taylor of the

United States and Alfred Wegener of Austria drew their elaborate continental drift theories.

In recent years R. A. Daly of Harvard has elaborated on the probabilities of folded mountains resulting from the gravitational sliding of continents. He has cleared up a number of points of opposition and has added much new material. According to his theory, the geosynclines bordering the continents cause the crystalline rock crust, composed of the granite shell and the upper frozen layer of basalt, to sink deep into the glassy basalt layer which has less density than the crystalline rock above. Tension cracks allow the glassy basalt to work up through the crystalline belt and cause it to founder, thus removing the chief source of resistance to the gravitational sliding of the continent toward the ocean basin. The light, unconsolidated sediments therefore, resting on the readily deformed basaltic glass are easily folded and thickened by the advancing continental mass. The more rapid movement of the lands nearer the ocean than of the lands farther inland, would cause tension cracks to develop some distance back from the continental border, with block-faulting and depression, as for example the Great Basin in relation to the Sierrras and the Coast Range, and the Triassic basins to the Appalachians. Also the more rapid advance of the continental mass toward a great ocean deep, than elsewhere, explains the arcuate character of such island festoons as that of the Aleutian Arc and the Japanese Arc.

Further, according to this theory, as folding of the weak sediments continues, more and more of the underlying crystalline rock is foundered. As time goes on the lower portion of the zone of crumpled sediments is melted and the great masses of foundered crystalline rock are either melted or turned to glassy material. Because of the advance of the continental border over the area of foundered rock the increase in volume of the foundered rock through melting or vitrification would cause a gradual elevation of both the geosynclinal and the adjacent continental areas.

This theory, then, accounts for the formation of the arcuate mountain pattern, the folding, the tensional faulting further inland and the later uplift of the folded mountains and the bordering continental areas, such, for instance, as the Colorado Plateau. This theory, along with that of Joly's, favors the possibility of a certain amount of continental drift.

The weakness of the theory lies in its assuming such great mobility for the glassy basalt, and in the nonconformity of the theory with the structure of the tensional basins.

JOLY'S RADIOACTIVE THEORY

According to the Joly Radioactive Theory all known rocks have radioactive substances chiefly in the form of uranium or thorium. These two heavy atomic weight elements are slowly changing to substances of less atomic weight and finally to lead. In the change, heat is given off. Man has been unable in any way to change the rate of decomposition by extreme temperature and pressure changes. At the known rate of decomposition one-half of the uranium will have disappeared in 5,000 million years and ½ the thorium in 13,000 million years. Granites and acid igneous rocks contain about twice as much radium as the basic igneous rocks and the sedimentary rocks. The loss of heat at the earth's surface is known to be about the same as the computed amount generated by radioactive substances in the 35 mile crust. In the thicker continental crusts more heat is generated than is lost, and everywhere in the earth beneath the crust, radioactive heat is constantly accumulating. The latent heat of fusion of basalt is 100 calories per gram. It would, therefore, take about 30,000,000 years for sufficient heat to accumulate to bring the sub-crustal basalt to the melting point.

Radioactive substances have been undergoing decomposition and causing rise in temperature since the earliest geological times as shown by radioactive haloes in Archean rocks, nearly two billion years old.

When fusion of the basaltic crust takes place, convection currents concentrate the heat on the crystalline rocks of the overlying crust. This crust is gradually thinned by melting from below, until the more rapid loss of heat, through the thinned shell, checks the process. If we assume with Prof Joly a 70 mile thickness of melting, the general 10 per cent volume increase will lengthen the earth's radius by 6.5 miles. This elevation would cause general tension and cracking, especially of sub-ocean crust and continent borders, with the outpouring of much lava.

Since the continents are in isostatic equilbrium (floating in a sea of lava), with decreased lava density they would stand relatively less high above the sea then formerly, provided the lava could escape, and we would have a period of ocean-basin spread and shallow sea transgression. With such expansion, the circumference would be, according to Joly, between 30 and 40 miles longer than normal.

When crystallization and shrinkage begin, as a result of cooling, the geosynclines are folded and pushed deeper into the earth. With continued crystallization and differential settling, the ocean basins are depressed more than the lands, and are underthrust against the conti-

nental borders. With the return of the magma to a denser condition, the greatly thickened zone of relatively light sedimentary rock, in the geosyncline, is slowly elevated to a lofty mountain range, while the continents are considerably elevated. According to this theory the folding occurs during the late molten and early crystalline stages, and most of the elevation comes later.

During the molten stage the tidal and precessional forces cause the crustal masses to have a slow migration westward, thus allowing the highly heated sub-continental magma to be carried into the ocean basin segment, and the continents to come to rest over the somewhat cooler sub-ocean portions. It is thought that this relatively westward drift of the crust accounts for the great outpouring of basalts usually on the western side of the continental masses, as that of the Columbia River Plateau of western North America, the Deccan Plateau of western India, the Hebridean Area west of Europe and the Disco Flow west of the mountains of Greenland. By this same force, the continent with the deepest keel and the greatest frictional resistance to drift, would have the least westward displacement. Asia, with the highest mountains, and therefore the deepest keel, should in the next molten period migrate less than the rest, as indeed it may have done in the former molten periods. The fact that South America has a deeper keel than North America would also explain its less westward migration.

According to the Joly Theory the earth is now in the solid crustal stage, with continental growth not yet completed.

This theory has the advantage over all others of logically explaining the periodic flooding and elevation of the continents. It also successfully explains the folding of the mountains and the igneous activity associated with the early part of mountain building. It also supplies a logical explanation for the elevation of the mountains, long after their folding.

If the continents are shifted to the west during the hypothetical molten stage there should be an accumulation of acid rock material, originally molten, on the east side of the continents and, through this action, they should be building out a thinner crust towards the east.

Since the acid rocks of the continents contains about twice as much radioactive material as the basic rocks of the sub-crust, the thicker continents should reach, in their basal portion, a condition of fusion before the basic rocks of the sub-crust. This would bring about an elevation of the continent, followed by injection and ultimate spreading of the continent, with folding of the continental borders; all entirely inde-

pendent of the general basaltic fusion. This source of folding has been emphasized by both G. R. MacCarthy and W. F. Prouty in recent articles.

ASTHENOLITHS

Bailey Willis in his recent articles on "Continental Genesis" and "Metamorphic Orogeny," has laid stress on the importance of crystal growth in the metamorphic rocks as a source of lateral compression in mountain building. According to his theory, tidal and rotational forces have developed diagonally orientated strain zones in the earth outside the inelastic core. These strain zones in the deeper earth are favorable to rock fusion. The magma thus formed tends slowly to melt its way toward the surface along the zone of strain and to pond, along with other magma locally formed, beneath the poorly heat-conducting, crystalline outer crust. These local pockets of molten rock may reach dimensions of several hundred miles. The cumulative, shearing stresses, associated with the growth of such an asthenolith, ultimately cause eruption around its border. This is followed, finally, by a central collapse. According to Bailey Willis, some of the extinct asthenoliths are marked by the larger depressions in the ocean basins, while the present active forms are marked by certain deeps "characterized by great seismic activity and beside which rise great mountain chains of volcanic or intrusive formations." During the life of this molten pocket, metamorphism of the surrounding rock is taking place with the formation of a flock of new minerals. The growth of these new minerals is largely in the horizontal plane, the direction of least resistance, and as the crystal growth exerts a pressure as great as the crushing strength of the crystal, and therefore the rock, we have here a tremendous lateral force in the areas of metamorphism. Such asthenoliths tend to form under both ocean and continent but those which form under the continents have a stronger tendency to approach the surface along the continental borders than elsewhere.

The above theory of asthenoliths would explain both the igneous activity and the formation of the arcuate folds in the coastal island mountains of Asia. While the assumptions of the theory do not seem to be necessary to account for local pockets of molten rock beneath the earth's crust, the application of the force of growing crystals, in association with molten areas, explains certain facts in orogeny better perhaps than any of the other theories.

CONCLUSIONS

The foregoing brief discussion of some of the better-known theories of the origin of folded mountains, shows that the question of origin is far from being settled. Some of the newer and more startling theories, such as the continental drift theory, have been carried to absurd extremes by some of the more enthusiastic and less well balanced advocates. On the other hand a number of ultra conservative scientists, believing in absolutely fixed continents, can see no value in the drift theories. These reactions are according to the laws of human nature. I think it can be said in truth that none of the newer theories is completely in the right and that none is completely wrong. Here again we are travelling the same old scientific path.

No one, at the present, questions the truth of great horizontal and vertical movements in the earth's crust, in the formation of folded mountains, but only the causes back of such movements. Most geologists who believe in fixed continents and ocean basins, think also of the horizontal movements largely as the result of differential settling of continental and sub-ocean masses, in a radially shrinking earth; or they think it due to actual enlargement of the crust by wedge action of igneous injections or by the pressure exerted by great numbers of crystals growing, in horizontal orientation, in the zone of metamorphism.

As a result of lateral compression from one or many causes the rigid crust of the sub-oceanic section is gouged into the continental section, beneath its more rigid superstructure. This underthrusting by the ocean segments results in an overthrusting by the continents. Since the Pacific basin is larger and deeper than the other ocean basins, it has a greater and more unbalanced underthrust than other ocean segments and we have, therefore, the greatest foredeeps in the Pacific.

The geosynclines provide the location for the maximum buckling. Their elevation provides sediments for new geosynclines.

The theory of drifting and of sliding continents give us additional causes for horizontal compression. They also give reasons for directionally variable forces of tension and compression.

Arcuate mountains are best explained by either the gravitational sliding of continents or by Bailey Willis's theory of asthenoliths.

The Joly hypothesis of a periodically molten sub-crust, removes one of the chief objections to the theory of continental migration, namely, the non-mobility of the earth. It also makes possible the explanation of a number of facts previously unsatisfactorily explained.

The present day theories taken as a whole account for all the observed facts in connection with mountain building, but it will be many years before there can be a general agreement as to the most important cause of either mountain folding or mountain uplift. Fortunately some of these theories can be tested. Exact longitudinal determinations, by use of radio, over a period of years, should give definite information concerning the drift of continents. Intensive geophysical tests should continue to yield facts about the earth's interior. Tidal and precessional forces are being cheeked by the mathematicians. Geological materials and structures are being scrutinized, with the new theories in mind. In short the subject is undergoing a rigid quantitative analysis.

We shall probably find that in the great work of mountain building, not one or two causes, but many causes, are active, and that not all folded ranges are built in the same way.

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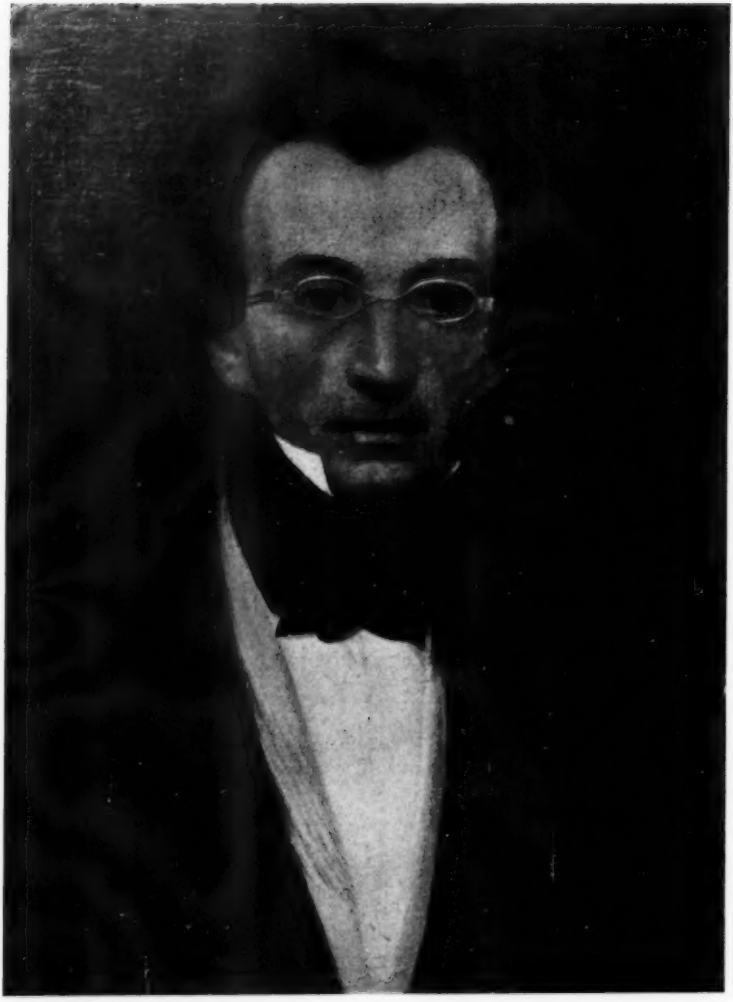
PLATE 2



NICHOLAS M. HENTZ

NICHOLAS MARCELLUS HENTZ[1]

By Collier Cobb

Plates 2 and 3

In 1885, while working in the Annisquam Seaside Laboratory of the Boston Society of Natural History, on a week-end visit to Harvard College, I met Dr. Oliver Wendell Holmes who was with Professor Andrew P. Peabody, Plummer Professor of Christian Morals, Emeritus.

Dr. Holmes said to me: "If you know much about Chapel Hill you must have heard of my friend, Nicholas Marcellus Hentz. He was professor of German at the University of North Carolina a generation or more before your day; and he was a great friend and an active correspondent of Dr. Thaddeus William Harris's. While most of their correspondence was about scarabees, Hentz was really a very celebrated arachnologist, spider specialist. His book on *The Spiders of the United States*, is even now the most valuable work we have on this subject. Both his correspondence with Dr. Harris and his *Spiders of the United States* were published in The Journal of the Boston Society of Natural History.

"Some of Dr Hentz's papers had appeared in Silliman's Journal and a few in the Journal of the Philadelphia Academy of Arts and Sciences. Hentz not only made wonderful colored pictures of the spiders, but frequently etched or engraved the plates himself. He painted life-like miniatures, and he even painted a remarkable picture of himself. Only two of his papers had been published in any form at the time that he submitted them to the Society, but later Sam Scudder, Secretary of the Society, collected them and published them in its *Proceedings* as a supplement to the original publication in its Journal.

"You may possibly recall what I said about the Scarabee in my *Poet at the Breakfast-Table*. I had both Hentz and Harris in mind when I wrote that, and I should be thoroughly ashamed of the way I treated my good friends in that book. I am sure you will be a member of the Boston Society of Natural History some day, and I believe if you will

[1] A brief note on Hentz's life by Geo. F. Atkinson with bibliography appeared in this Journal, **4**: 13. 1887.

go to the Secretary and tell him what I say he will give you a copy of the correspondence between Thaddeus Harris and my Chapel Hill friend, and also a copy of Hentz's *Spiders of the United States.*"

I went at once to the Boston Society of Natural History where I found Dr. Sam H. Scudder, a distinguished entomologist, with a world-wide knowledge of *Lepidoptera, Orthroptera,* and other orders of insects, and probably the world's foremost authority on fossil insects. He was also editor of *Science,* which journal he had started in 1883. With Dr. Scudder was Mr. James H. Emerton, himself a famous naturalist, illustrator of zoölogical publications, constructor of remarkable models for museums, and a world authority on the structure and habits of spiders.

Mr. Emerton told me that the Boston Society of Natural History had most of the Hentz collection, which he proceeded to show me; and he also told me that Dr. Hentz had made for himself a secure place in the world of science as an arachnologist. This was certainly a red-letter day for the North Carolina student; but I could not help feeling that all these newly acquired friends regarded me as belonging to an order of insects whose habits they had heretofore had but little opportunity to study.

The Secretary gave me a bound volume of the Entomological Correspondence of Harris, published in 1869 as vol. I of Occasional Papers. More than half the book, 207 pages, is devoted to his correspondence with Professor Hentz; the next thirty pages (to p. 237) to letters to and from John Lawrence LeConte; through page 248 with Miss Margaretta Hare Morris; and the remaining pages of the correspondence consists of letters to Say, Zimmerman, LeBarron and Higginson, with one each from LeBarron and Higginson. Later Mrs. George N. Hatch, West Palm Beach, Florida, a granddaughter of Nicholas Marcellus Hentz, gave me the original colored drawing of the spider which is reproduced on plate 3.

The Society published in 1875 vol. II of its Occasional Papers, with the title "The Spiders of the United States. A Collection of The Arachnological Writings of Nicholas Marcellus Hentz, M.D." This was edited by Edward Burgess, with notes and descriptions by James H. Emerton, and it contained a brief sketch of Professor Hentz's life written from materials furnished by his eldest son, Dr. Charles Arnould Hentz, of Florence, Alabama.

It is better to give you that sketch as published in "The Spider Book" than to attempt an independent account of my own.

"*Nicholas Marcellus Hentz* was born in Versailles, July 25, 1797. His father, an advocate by profession, was actively engaged as a politician at the time of Hentz's birth, and had been, shortly before this event, obliged to flee from his home in Paris, and to conceal himself in Versailles under the assumed name of Arnould. To the agonizing fears and alarms which his mother was obliged to undergo during this period, Hentz was wont to attribute the peculiarities of his nervous system, which were, as will be seen, very remarkable.

"At the early age of between twelve and fourteen years he began the study of minature painting, for which he showed great talent and became highly proficient. He soon, however, became interested in medicine and entered the Hospital [Val-de-Grâce as a student. His son still possesses, in an old parchment-covered memorandum book, the following record in Hentz's then boyish hand-writing, 'le vendredi 22 octobre 1813, j'ai été au Val-de-Grâce, M. Hentz.' There he remained, busied with his studies and duties as hospital assistant, until the fall of Napoleon, when his father was proscribed and obliged to flee to America, whither Nicholas and one of his brothers accompanied their parents.

"The party sailed from Havre-de-Grâce, in the bark 'Eugene', Jan. 22, 1816, and arrived in New York City on March 19. Here and in Elizabeth Town they spent a few weeks in collecting their personal effects and making arrangements to move into the interior, an undertaking which was then quite formidable. They arrived in Wilkesburg, Pennsylvania, in the latter part of April, where it is probable that Hentz's parents finally settled.

"Hentz himself for several succeeding years lived in Boston and Philadelphia, where he taught French and miniature painting. He also passed a short time on Sullivan's Island, near Charleston, S. C., as tutor in the family of a wealthy planter, a Mr. Marshall. All this time, whenever leisure hours allowed it, he was engaged in entomological studies, directing his special attention, as has already been said, to spiders. While in Philadelphia he became intimate with the naturalist, Le Sueur. Le Sueur was accustomed to etch his own drawings, and having the use of his press, etc., Hentz made etchings of some of his spiders, as well as of an alligator, which he had dissected to study the nature of its circulation.

"In the winter of 1820–21, he attended a course of medical lectures in Harvard University, but finally abandoned the study of medicine, and engaged himself as teacher in a school for boys at Round Hill, Northampton, Mass., where Bancroft, the historian, was also employed. Here

he was married to Miss Caroline Lee Whiting, the daughter of Gen. John Whiting, of Lancaster, on Sept. 30, 1824, and Mrs. Caroline Lee Hentz became afterwards well known as a poet and novelist.

"Soon after their marriage, Hentz and his wife removed to Chapel Hill, N. C., where he had been offered the chair of modern languages in the State University. In 1830 he moved to Covington, Ky., to take charge of a female seminary, and a year or two after, to Cincinnati, where he was similarly engaged. 'A graceful allusion,' writes Dr. Hentz, 'is made to them during this time, in Mansfield's "Life of Daniel Drake," 1855, p. 226.'

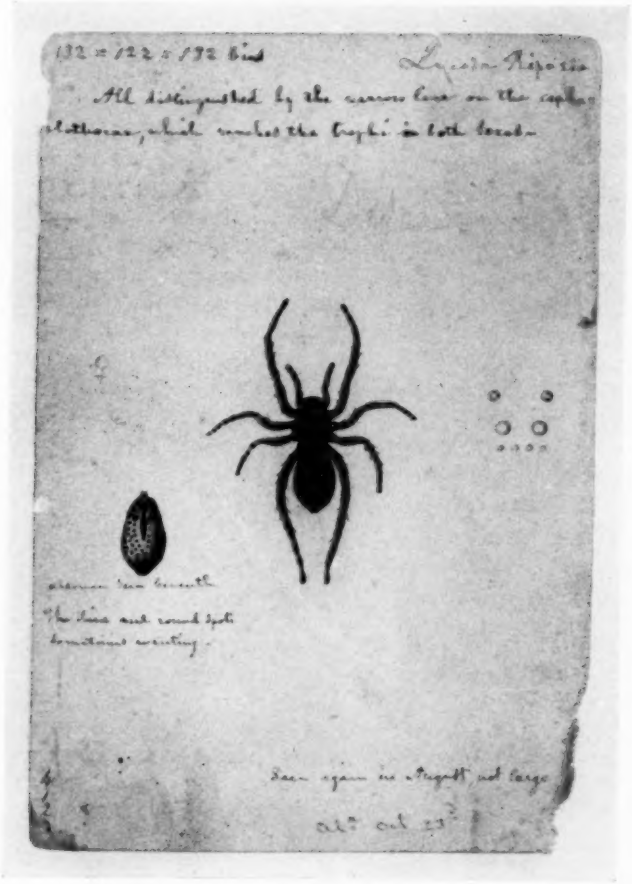
"In 1834 they again removed to Florence, Ala., and there for eight years conducted a flourishing school, the 'Locust Hill Female Academy.' In 1842 they went to Tuscaloosa, and in 1846 to Tuskegee, both towns in Alabama, and the following year to Columbus, Georgia, all the time engaged in similar teaching.

"In the latter place in 1849, Hentz's health began to fail, his whole nervous system giving away. He grew gradually more and more infirm, and became regular user of morphine, which he took daily for several years before his death. He moved, finally, to the residence of his son Charles in Mariana, Fla., where he died November 4, 1856.

"In person, Prof. Hentz was a small, spare man, about five feet and a half in height, and weighing only one hundred and ten or one hundred and fifteen pounds. Although of a genial, affectionate, and generous nature, his peculiarly nervous organization made him often morbidly sensitive and suspicious, and a prey to groundless fears, which not a little marred his enjoyment of life. He was educated in the Roman Catholic religion, but in 1835 joined the Presbyterian Church. During his whole life he had a most remarkable habit of suddenly resorting to mental, ejaculatory prayer. Without regard to circumstances, in any place, or among any people, he would sometimes, without apparent external reason, take off his hat, or perhaps drop on his knees, press his hands to his forehead, and raising his eyes heavenward, remain in more or less protracted prayer. He had also several regular places for this singular custom, as before his study-door, which he never entered without stopping a moment in silent prayer, and beneath a picture he had made of the 'All-seeing Eye'; indeed, the constant pressure of his forehead against the wall in these places left an indelible mark.

"He was extremely fond of exercise, and his Saturday half-holidays were invariably spent in long walks with his sons in the woods, carefully collecting insects and observing their habits. For amusement he delighted in fishing and gunning.

PLATE 3



LYCOSA RIPARIA. REPRODUCED FOR THE FIRST TIME IN COLOR FROM AN ORIGINAL BY NICHOLAS MARCELLUS HENTZ

"He was a great friend of Dr. Thaddeus Wm. Harris (one of his sons, Dr. T. W. Hentz of Columbus, Ga., was named after him), and after separated from him by his own removal to the South, a constant correspondence, mostly entomological, was kept up between the two friends, a portion of which, as already remarked, was published in the first volume of this series."

Mrs. Spencer says of the Hentzes: "These were people who would have been distinguished anywhere. From the first they were the intimate friends of the Phillips family, and when in 1830 they left Chapel Hill they seemed to have looked lovingly back to what Mrs. Hentz called the 'kindness, warm feeling, hospitality and union of Chapel Hill.' Professor Hentz was called by Dr. Mitchell 'the foremost entomologist of America,' this study being pursued by him by way of a hobby. Mrs. Hentz was of a literary turn, wrote verses and a play or two, and after she left Chapel Hill produced several novels, books successful in their time, but long forgotten." Mrs. Spencer also says that her story *Lovel's Folly* contained half a dozen Chapel Hill portraits, delineating especially the dignified, family-proud house-servants of Dr. Caldwell's, types which must have been very interesting to this New England woman. Both of the Hentzes could draw, and painted in waterworks. (From *Old Days in Chapel Hill*, pages 25 and 26.)

A GYNANDROMORPH OF MEGACHILE LATIMANUS SAY[1]

By Theodore B. Mitchell

Plate 4

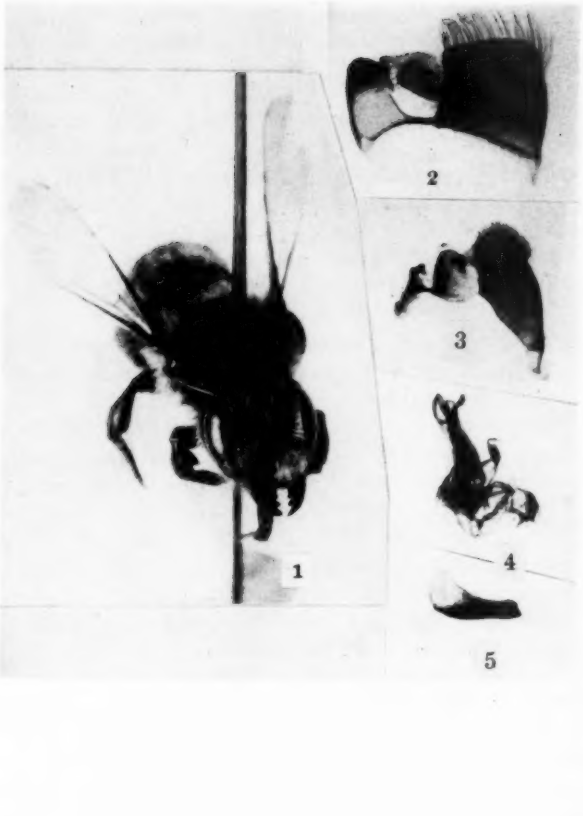
An interesting specimen of *Megachile latimanus* Say was found in a collection of bees of that genus sent to me from Colorado by Mr. S. C. McCampbell for identification. It is a partial lateral gynandromorph, the mandibles, antennae, thorax and legs being entirely female in character so far as external examination will show. The gynandromorphic condition is seen in the clypeus (See plate 4, figure 1) and the abdominal sternites. The left half of the clypeus is male in character, having a dense covering of long pale pubescence which entirely covers the surface, and the apical margin is produced just to the male side of the center. The right side is female, having but very thin pubescence which does not obscure the surface to any degree, and the apical margin lacks the protuberance. A further difference between the two halves is seen in the puncturation, this being relatively coarse on the female side, but very minute and dense on the male side, and this difference extends above the clypeus onto the supraclypeal area.

The division of the abdominal sternites into left male and right female halves is remarkably distinct and abrupt. The first sternite does not show remarkable differences, since the sexual dimorphism is not marked in this plate. The second, third and fourth sternites, however, show the contrasting sexual characteristics very conspicuously, the right half of each having a well developed brush of scopal hairs and the left half being bare except for the fine inconspicuous pubescence normally present on the male. Also, the apical margin of the fourth is broadly membranous on the male side, considerably produced beyond the straight and unmodified apical margin of the female side.

Of more interest than any other structures are the fifth and sixth sternites, the seventh tergite, and the genitalia. In normal males of this genus the fifth and sixth sternites are telescoped inside the abdomen,

[1] Contribution from the Department of Zoology and Entomology, North Carolina State College, published with the approval of the Director of the North Carolina Experiment Station as paper No. 47 of the Journal Series.

PLATE 4



entirely hidden, and very highly modified. The same plates in the female are external in location and covered with scopal hairs, just as the more basal plates. Moreover, in the male there is a well developed, though small, seventh tergite, not evident in the female. The seventh sternite (male) is entirely membranous in most species, and an entirely hidden eighth segment may be found if a specimen is dissected, the tergite being entirely membranous, the sternite thin, but definitely sclerotized. The male genital armature is contained between the tergite and sternite of this eighth segment, and is a relatively large structure, with large stipites and sagittae, markedly different from the sting and its associated plates in the female.

In this specimen the abdomen was slightly twisted because of the anomalous condition of these apical plates, since the female side of each was entirely exposed, while the male side was in part at least hidden beneath the fourth sternite. These plates and the genital armature were dissected out of the specimen and mounted, and the accompanying photographs will show the distinct division of the fifth (fig. 2) and sixth (fig. 3) sternites into male and female halves.

The genital armature (fig. 4) also shows the same division into left male and right female halves. A well developed though somewhat misshapen stipes and sagitta are shown in the photograph, while a half of the female sting, with one sting palpus, and to a less degree the associated plates may be distinguished. These were not separated during dissection, and the photograph shows them essentially as they were associated together in the abdomen of the specimen. The seventh tergite (fig. 5) consisted of a left half only, no corresponding female structure being connected to it so far as could be determined.

It would appear that the anomalous condition in this specimen differs from the condition of the material which I described in a previous paper.[2] The term "intersex" was applied to all of those specimens because of the apparently intergrading nature of various regions and structures, with no sharp lines of demarcation between the definitely male and definitely female parts. The occurrence of such intersexual forms was thought to be due to some physiological change, due to some environmental factor during development, such for instance as parasitism, resulting in a change of direction of development from one sex to the opposite one. Thus all of the specimens described had started development along female lines, but had switched to the male type of development before the character of all of the structures had become fixed. Thus structures

[2] Trans. Am. Ent. Soc. 54: 321–383. 1929.

determined early in development were female in character, while other parts not definitely determined at the time of change became male in nature, those in process of determination at the time of change becoming intermediate.

It is evident that the specimen here described is entirely different in character from these others, being a true gynandromorph, and originating in all probability through some accident in the distribution of chromosomes, this resulting in certain tissues receiving the female complement of chromosomes, and in others receiving the male complement.

Only one other true gynandromorph has been recorded in this genus up to this time. Stenton[3] described a gynandromorphic specimen of *Megachile willughbiella* Kirby which also was a partial lateral gynandromorph, with the right side female and the left side male, but the genital armature was entirely male in character. The legs of each side were apparently contrasting, as also the other structures, as he states that ". . . . either side retains the usual outward characters of its respective sex."

[3] Entom. Mag. **45**: 188. 1909.

NORTH CAROLINA'S SINGING ORTHOPTERA[1]

By B. B. Fulton

The study of insect songs has four things to recommend it. (1) It may become an interesting hobby that one can pursue out of doors, after regular working hours, and which is satisfying to both the hunting and collecting instincts. (2) For the animal ecologist it may serve as a tool in the study of ecological distribution. The range and relative abundance of singing insects can be determined with comparative ease and accuracy. (3) To the student of evolutionary problems the interest lies in the fact that the songs of insects often serve as indicators of physiological varieties within the species. In the process of evolution physiological differentiation sometimes precedes the appearance of morphological characters and is most readily detected by differences in song habits. (4) To the taxonomist or collector a study of insects songs is valuable because it aids in the detection and capture of new or rare species.

Among our native species of Orthoptera there are three methods of sound production. The crickets (Gryllidae) and the katydids or long horned grasshoppers (Tettigoniidae) all sing by vibrating the front pair of wings. The edge of one wing scrapes a rasp on the under side of a specialized vein of the other wing. The short horned grasshoppers (Acrididae) have two other methods of producing sounds. Some make a loud clattering noise while flying by striking the front wings against the hind wings. When not in flight, some produce a faint rasping noise by rubbing the hind femora against the outer side of the front wings. Either the leg or the wing may be provided with a fine rasp. Sounds produced by the Acrididae have few characteristics to distinguish one from the other and have been omitted from the key. They are active only during the day. Most if not all of the Gryllidae and Tettigoniidae sing at night although many of them also sing during the day.

Some species have the ability to vary their songs somewhat and several have two types of songs so distinct that they would not be recognized as coming from the same insect. In cases where both types are

[1] Published with the approval of the Director of Research as Paper No. 46 of the journal series.

commonly heard they have been included in the key with a number in parenthesis after the species name. In the Tettigoniidae the factors influencing the use of one kind of song or the other are not clearly understood but they seem to involve light and temperature. The large angular-winged katydid, *Microcentrum rhombifolium*, is the best example of a versatile songster in this family. The sound most commonly heard is a rapid series of ticking sounds made by drawing the wings together slowly so that each tooth of the file makes a distinct sound. At certain times nearly all of this species will be heard making a single loud rasping note by closing the wings quickly.

With the Gryllidae having more than one type of song, the choice seems to be influenced by the psychological state rather than physical environment. Some species have a special song which is used only when actively courting the female. Several species of Nemobius have this peculiarity, the mating song differing from the usual calling song in length and frequency of notes or in rhythm. Even more versatile is the mole cricket, *Scapteriscus acletus*, which is common in the southeastern part of the state. Its calling song is a continuous loud whistle, which is usually heard at night while the male is sitting at the entrance of a burrow. When courting the female it uses a rhythmical intermittent note. At other times, single chirps may be heard, especially when a colony is disturbed by an entomologist trying to dig them out of the ground. It seems probable that the single chirp may be a signaling or warning note. While relatively few species have more than one distinct type of song, the rate of wing movement in all species is so influenced by temperature that on extremely cool nights the character of the song may be considerably altered. Lowering the temperature prolongs the notes, reduces the frequency and lowers the pitch. Thus some songs that normally appear as continuous sounds may on cool nights become a series of distinct notes, or a note that usually lasts only a few seconds may be prolonged for a half a minute.

Rhythm and Synchronism

In the quality of rhythm the songs of the Orthoptera exhibit all possible degrees. Some have absolutely no rhythm, the notes being delivered at irregular intervals. Some show a slight regularity in rate of delivery while others have a repetition of notes that is definitely rhythmical but which does not hold constant at all times. Finally some have a constant rhythm, influenced only by temperature changes. A few of the last class go a step further and synchronize their notes so

that a group of singers gives the effect of being under the direction of a leader. Among the Orthoptera of this state only three species are known to synchronize. These are *Oecanthus niveus, Cyrtoxipha gundlachi columbiana,* and *Neoconocephalus exiliscanoris.* The first is the well known snowy tree-cricket and is found in this state only in the mountain regions. The second is a smaller cricket, common in trees in the piedmont and probably more widely distributed. The third is a large cone-headed grasshopper which appears to be rare in the state.

PHYSIOLOGICAL VARIATIONS

There are three races of a small ground cricket, *Nemobius fasciatus,* which have distinct songs and live in different habitats. The physiological variations in this case are accompanied by slight structural differences so that it is possible to give these races subspecific rank although it is very difficult to separate them on morphological characters alone.

The large ground cricket, *Gryllus assimilis,* has been observed to have at least two types of songs, which are associated with certain habitats and seasons. This species was formerly split into several species on the basis of a few extremely variable characters. The writer has not yet attempted to discover whether the recognized song types are correlated with any of these structural characters.

The small bush cricket, *Anaxipha exigua,* displays three kinds of songs in different individuals but so far no correlation has been discovered between these song types and habitat. Another member of this genus, *Anaxipha pulicaria,* has two song types which are definitely associated with different habitats. All that have been heard in fresh water marshes have a continuous song, while in the salt marshes all have an intermittent song. The wingless bush cricket, *Cycloptilum bidens,* occurs among clumps of sea oats on the coastal dunes and inland among the underbrush of pine woods. In the former habitat it sounds its notes at about twice as fast a rate as in the latter habitat.

Some song differences seem to be a matter of regional dialect. The true katydid, *Pterophylla camellifolia,* acquired its common name from its constant repetition of a three-syllable song phrase. In this state it sings in a southern dialect, usually with four syllables in each phrase and as often with five as with three. Snodgrass (4) states that in New England the katydid generally sounds only two syllables. It would seem that the name "katydid" must have been given to it at some point between North Carolina and New England.

The small round-winged katydid, *Amblycorypha rotundifolia*, in the sand hill region has an entirely different song than the same species in the mountains, and neither song entirely fits the descriptions of its song as observed in other places.

KEY TO SONGS OF NORTH CAROLINA KATYDIDS AND CRICKETS

The preparation of a key for anything so intangible as insect songs is a difficult task. Probably other observers perceive qualities in a song different from those which have impressed the writer. The time element is the only feature which can be measured with any accuracy and unfortunately this is subject to the effect of temperature, for which some allowance must be made. A thermometer has not often been at hand when the observations were made, but unless otherwise mentioned the descriptions found in the key do not apply to abnormally low temperatures. The writer believes that the key will be useful to students of insect songs and that its publication may stimulate others to take up this interesting study.

Group I. Tettigoniidae (katydids or long horned grass hoppers).

Rasping, buzzing, fluttering, or ticking sounds, having no quality of musical tone. Divided below into 5 groups, A to E.

A. Continuous buzzing or fluttering sound, or with breaks of only a fraction of a second occurring at irregular intervals.

1. Loud buzzing sound; night.

a. Midsummer to late summer, very loud. In tall grass, weeds or bushes.

Neoconocephalus robustus crepitans (Scudder)

b. Late summer and fall, not as loud as last. Usually in grass.

Neoconocephalus retusus (Scudder)

c. In April and May, song sometimes with brief breaks occurring at intervals of a few seconds. In tall grass weeds or bushes.

Neoconocephalus triops (Linn.)

2. Very faint fluttering sound, audible only a few feet away. In grass; day and night.

Conocephalus strictus (Scudder)

B. Single notes or brief rapid series of 1 or 2 seconds duration; intervals between notes or series at least 2 seconds and not regular; never constant singers.

1. Brief single note, described as "zip" or "zeet;" made by a simple closing of the wings.

a. Very loud and sharp, often repeated at 2-3 second intervals for a minute or more; in trees and bushes; at night.

Microcentrum rhombifolium (Saussure) (1)

b. Less loud, sometimes repeated a few times at intervals of several seconds; in tall weeds, bushes, small trees; late afternoon and night.

Phaneroptera furcata furcata (Brunner) (1)
Phaneroptera cuneata (Morse) (1)
Phaneroptera curvicauda (De Geer) (1)

2. Short series of brief confluent notes, made by vibrating the wings a few times while closing them; late afternoon and night .
   a. Rasping sound, described as "zee-zee-zee-zeet," not regularly repeated.

Phaneroptera furcata furcata (2)
Phaneroptera cuneata (2)
Phaneroptera curvicauda (2)
Phaneroptera texensis (Saussure-Pictet (1)

   b. Shorter, crisper rasps, like tapping two heavy walled glass bottles together lightly. Made by 2 or 3 rapid wing movements. Has been described as "it-z-zic" or "kizizik." Repeated a number of times at intervals of 3 or 4 seconds or longer. In tall weeds, bushes, trees; at night.

Amblycorypha oblongifolia (De Geer)

   c. More prolonged sound (1–1½ seconds); 8 to 12 confluent notes, rapidly repeated; a softer sound than any other under B; increases in volume after starting. Usually in low meadows or marsh; late afternoon and night.

Phaneroptera texensis (2)

C. Each song distinct and running through a regular program, starting with a faint buzz which gradually increases in volume and develops a rapid beat or undulation, then it changes to a rapid series of louder lisping notes and terminates with a brief vibrant note like the shaking of a dry pod full of small seeds. This last phase is then repeated a few times, and is followed by a period of silence before the next song is is started. In tall weeds and bushes; at night.

Amblycorypha uhleri Stahl

D. Song a more or less regular repetition of similar notes; rest intervals not over 1 second, generally a small fraction of a second.
   1. Notes in series of various length; series separated by longer and variable period of rest (at least 1 second).
      a. A rapid series of ticking or tapping sounds at rate of about 7 or 8 per second, series lasting about 2½ to 3 seconds. In trees and bushes; night.

Microcentrum rhombifolium (2)

      b. Rasping sounds.
         (1) Series of 8–10 at rate of 2 per second; loud. In salt marshes.

Homorocoryphus malivolans (Scudder)

         (2) Longer series, 10 to 30 notes, intervals between notes very brief, observed rates at night 5 to 16 per 10 seconds. Woods and thickets, May to Aug.; mostly at night.

Atlanticus pachymerus (Burmeister)

         (3) Series of 12–16, the first 4 to 6 notes longer and at rate of about 2 per second, then notes become shorter and rate

increases to about 4 per second; entire series lasting 4 or 5 seconds (observed at 74°F.). On oaks in sand hills; at night.

Amblycorypha rotundifolia (Scudder)

(4) Series of brief rasps, too rapid to count, probably 10 to 12 per second; each series ½ to 2 seconds duration; occasionally longer; rest intervals 2 to 4 seconds. (Observed between 65° and 70°F.). On bushes in mountains; at night.

Amblycorypha rotundifolia (Scudder)

2. Loud harsh notes in series of 3 to 5, duration of series less than 1 second, series constantly and rhythmically repeated. With anyone individual the number of notes per series is fairly constant, with occasional series having 1 more or 1 less. Most individual have 4 notes as the most common number. In tops of trees; at night.

Pterophylla camellifolia (Fab.)
(True katydid)

3. Notes continuously repeated.

a. Notes of harsh rasping quality, rhythmically repeated at rate of 3 or 4 per second. At close range the sound never entirely ceases and is in reality a continuous buzz with a pronounced beat or rhythmical pulsation. In spring only; at night.

Pyrgocorypha unicincta (Harris)

b. Short, sharp notes repeated rhythmically faster than one can count. In high grass or weeds; mountains; some singing in daytime, more at night.

Neoconocephalus ensiger (Harris)

c. Prolonged, weak fluttering notes at rate of about 4 notes in 10 seconds. In tops of pines; day and night.

Orchelimum minor Bruner

d. Very faint buzzing notes, audible only a few yards away, 1 or 2 notes per second; occasional notes preceded by a few rapid lisps as if stuttering. In brush; mountains; day and night.

Conocephalus nemoralis (Scudder)

E. Alternating phases of short and long notes.

1. Very faint, audible only a few feet away.

a. A rapid series of faint lisps preceding a prolonged buzz, regularly repeated. In grass; day and night.

Conocephalus fasciatus (De Geer)

b. Long phase may be repeated 2 or 3 times between each series of lisps which usually do not exceed 3 or 4 in number. Extremely faint. Grass in wet places, either in woods or open marsh.

Conocephalus brevipennis (Scudder)

c. Very irregular repetition of long notes of about 2 to 3 seconds duration and series of short notes at varying rates of 3 to 6 per second. Short notes do not have the lisping quality as in

two preceding species, but are a brief buzz of the same quality as the long note. On low bushes in open woods; day and night.

Odontoxiphidium apterum Morse

2. Louder, distinctly audible at least 5 yards away.

a. One (sometimes 2) brief lisps followed quickly by a long note (½ second) repeated regularly at rate of about 16 per 10 seconds. Low places, on tall grass, weeds, bushes; day and night.

Orchelimum erythrocephalum Davis

b. Two brief buzzes and 1 long, repeated regularly at rate of 6 series in 10 seconds. Observed on bushes near salt marsh; mostly at night.

Amblycorypha floridana carinata Rehn and Hebard

c. One to 5 brief lisps at rate of 2–3 per second; long note ½ to 1 second duration, rather weak and fluttering. On dune grass and borders of salt marshes; day and night.

Orchelimum concinnum Scudder

d. Four to 6 lisps at rate of 6 per second, long note ½ to 3 seconds duration; long note usually followed by brief pause. Borders of ponds and streams; day and night.

Orchelimum pulchellum Davis

e. Several short lisps too rapid to count; long note 2 to 6 seconds duration, loud, increasing in volume and ending abruptly; no pause between series or between phases. On tall plants in fields; day and night.

Orchelimum vulgare Harris

f. Similar to last and often found in same places; differs in having perceptible pauses between lisping phases and the long notes; less loud; long note is of uniform volume throughout and does not end so abruptly; day and night.

Orchelimum agile (De Geer)

g. Short notes a series of very rapid ticking sounds continued for 2 to 5 seconds, long phase a monotonous buzz of 10 seconds or longer; phases have no regularity of length and there are no pauses between. Edges of salt marsh; day and night.

Orchelimum superbum Rehn & Hebard

h. Song weak, fluttering; short notes 1 to 7 at rate of 3 or 4 per second, but when undisturbed these are usually omitted for long periods and song is almost entirely long notes, 1 to 4 seconds duration, pauses not over 1 second. Pond borders near coast; day and night.

Orchelimum militare Rehn & Hebard

Group II. Gryllidae (Crickets).

Shrill sounds having at least a trace of musical quality although never pure. In many cases a buzzing undertone is so pronounced that it is difficult to determine the pitch. The wing movement is usually rapid so that the sound produced

by the teeth of the file may be extremely high and accompanied by a low note due to the wing movement alone. The least musical songs in this group are not very loud. Most of the Tettigoniidae producing weak sounds have the alternating phases of short and long notes which is exceptional among the Gryllidae.

A. Continuous sound or with breaks of a fraction of a second occurring at irregular intervals.

1. With brief breaks at irregular intervals.

a. Relatively low pitched, clear, musical sound; in trees or vines; at night.

(1) Mostly in oaks.

Oecanthus exclamationis Davis

(2) In vines, bushes, trees.

Neozabea bipunctata (De Geer)

b. Less musical; on the ground; day and night.

(1) Moderately loud, shrill, with some tonal modulation or slurring; at close range with a rasping undertone; usually with a rapid vibrato produced by the wing strokes; in fields, spring and summer.

Gryllus assimilis Fab.

(2) Fainter, more buzzing and monotonous; breaks in song only a small fraction of a second so that sound is almost continuous; in upland grass, mostly on sterile soils; summer and fall.

Nemobius griseus funeralis Hart

2. Continuous sound, ordinarily without any breaks; day and night except as otherwise noted.

a. With rhythmical undulation or beat at least part of the time; with buzzing undertone; beats apparently due to variations in speed of movement, not to single wing strokes.

(1) Constant rhythmical pulsation or beat at rate of 5 to 7 per second; on ground in mesic forest; late summer and fall.

Nemobius maculatus Blatchley

(2) With a droning quality, variable in volume, part of time louder and with rapid beat, alternating with periods of reduced volume, lower pitch, without beat; on ground in low woods, marshes or under thick cover in moist spots in any habitat; summer and fall.

Nemobius carolinus Scudder

(3) See b (1) (e) below. *Phylloscyrtus pulchellus.*

b. Without rhythmical pulsation or beat.

(1) Not very musical sounds, with vibrato or buzzing undertone, or moderately weak and extremely high pitched.

(a) With a tinkling vibrato, a succession of sharp chirps at approximately 12 per second at ordinary summer temperatures; in grass; common only in mountains; late summer and fall.

Nemobius fasciatus fasciatus (De Geer)

(b) Similar to last but higher pitched, weaker, vibrato more rapid and not perceptible at high temperatures; gravel beds and sandy stream banks, not in thick woods; late summer and fall.

Nemobius bruneri Hebard

(c) Extremely high pitched, on marsh grass; late spring and early summer.

Anaxipha pulicaria (Burmeister)

(d) Similar to last; observed only in woods; on or near the ground; summer and fall; an uncommon song form.

Anaxipha exigua (Say)

(e) Shrill but not very clear sound, with a faint suggestion of the sound produced by a wooden Halloween rattle whirled on a stick; in bushes and underbrush of open woods; at times with a distinct beat.

Phylloscyrtus pulchellus (Uhler)

(f) A steady loud trill without modulations, at close range with a distinct buzzing undertone; on ground or in burrows, fields and lawns: at night only.

Anurogryllus muticus (De Geer)

(2) Clearer tone, like a whistle, not extremely high pitched.

(a) Shrill, moderately, loud, resembling sound of a tin whistle; day and night.

x. State wide distributions; on weeds.

Oecanthus nigricornis quadripunctatus Beutenmuller

y. Mountains; on coarse weeds, brambles.

Oecanthus nigricornis nigricornis F. Walker

z. Rare; on pine. (2 specimens collected by C. S. Brimley, in Hebard collection)

Oecanthus pini Beutenmuller

(b) Louder, clearer and lower pitched than last; mostly in bushes, vines in or near woodland. At night only.

Oecanthus latipennis Riley

(c) Very loud, clear, low pitched, singing at night in openings of burrows, moist sandy soil in southeast section. Calling song.

Scapteriscus acletus Rehn and Hebard (1)

B. Song of separate distinct notes.

1. Limited series of notes, all alike, faint and high pitched.

a. 3 or 4 notes in series; notes and rests about equal; rate of 6 per 10 seconds; very weak and with buzzing undertone. In dense thickets under trees or in woods; singing at night.

Cycloptilum trigonipalpum (Rehn & Hebard)

b. 3 to 10 notes in series; rate of 14–16 per 10 seconds; otherwise similar to last; on the coast; singing at night.

Cycloptilum antillarum (Redtenbacher)

c. 30 to 40 notes in series; rate about 2 per second; faint brief notes like a light tap on one of the high keys of a xylophone; among leaves or low undergrowth of woodland, most common in pine woodland, sings to some extent in daytime.

Cycloptilum bidens Hebard

d. 10 to 20 notes in series; rate about 4 per second; quality same as last; in tufts of sea oats, coastal dunes; at night.

Cycloptilum bidens Hebard

2. Notes repeated continuously, for indefinite period.

a. Notes over 1 second in duration. When several are singing at same time they give the impression of continuous sound since the notes are not synchronized and it is difficult to detect when they start and stop.

(1) Notes and rests about equal, usually 5 to 15 seconds each; weak, very high pitch; on ground; day and night.

(a) On sphagnum moss.

Nemobius palustris Blatchley

(b) Under dense low cover in marshes or moist places.

Nemobius cubensis Saussure

(2) Notes longer than rests (except when first starting to sing); lower pitched and more musical than last group. Usually in trees, bushes, vines. On warm nights the first two of this group sometimes sing with notes 15–30 seconds long and with very brief rests and for this reason have also been placed under continuous song, A, 1, a. When starting to sing before dark notes are 2–10 seconds with ½ to 1 second rests. The last species seldom has notes more than 10 seconds long and rest periods are 1 to several seconds.

(a) Usually in oaks.

Oecanthus exclamationis Davis

(b) Not common. Vines, bushes and trees.

Neoxabea bipunctata (De Geer)

(c) Various trees, sometimes found on herbs and bushes under trees.

Oecanthus angustipennis Fitch

b. Notes not over one second in duration. This group does not yield readily to further subdivision. Any single factor leaves certain species in an intermediate position. They have been arranged roughly on a basis of frequency of notes. Reference to other possible groupings outlined below may indicate the species by elimination.

On ground. (2) (3) (4) (8) (9) (10) (12) (14)
On low plants. (5) (6) (13)
On large bushes, vines. (1) (7) (13)
In trees. (1) (7) (11)

Notes synchronized (7) (11)
Rhythm almost constant, not synchronized. (8) (9) (10) (13) (14)
Regular repetition with somewhat changeable rate. (1) (2) (4) (5) (6) (12)
Length of notes and rate changeable. (3)

Known distribution limited to southeast. (3) (5) (6) (9)
Limited to mountain region. (7)

Clear tonal quality (1) (7) (8) (9) (11) (13)
Less clear (3) (5) (6) (10) (14)
With distinct buzzing undertone (2) (4) (12)

Loudest (1) (7) (8) (9) (10)
Weakest (2) (4) (5) (6)

(1) 5 to 8 notes in 10 seconds; rests distinctly longer than notes; clear, high pitched, moderately loud, trills, like "peep-peep;" in vines, bushes, trees; late afternoon and night.

Orocharis saltator Uhler

(2) 6 to 11 notes in 10 seconds; weak sound with buzzing or rasping undertone; on ground; many habitats; few singing by day, mostly at night.

Miogryllus verticalis (Serville)

(3) 6 to 10 notes in 10 seconds; weak, slightly creaky notes, increasing in volume and pitch after starting; very irregular in length, usually ½ to 1 second but occasional notes 2 to 3 seconds long; when mating, brief chirps 3 or 4 per second; in salt marshes under plants; day and night.

Nemobius sparsalusus Fulton

(4) 1 or 2 per second; weak buzzing notes. At a distance of a few feet each note can be heard to start with 2 (rarely 3) brief rises in volume after which it increases in volume to the end; sounding like a repetition of 2 short weak notes and one longer, louder note. On ground in woods; day and night.

Nemobius confusus Blatchley

(5) 1 to 2½ per second, rate variable, weak with buzzing undertone; underbrush on wooded sand ridges near coast; some singing during day, more at night.

Anaxipha pulicaria vittata (Bolivar)

(6) 2 to 4 per second, similar to last; on Juncus in salt marshes or on Iva on dunes; mostly at night. Apparently a physiological race.

Anaxipha pulicaria (Burmeister)

(7) 2 per second at 65°F., to 3 per second at 85°F., moderately low pitched, loud, clear notes with constant rhythm; synchronized with others near by; in trees or bushes in mountain region; at night.

Oecanthus niveus (De Geer)

(8) 2 to 3 per second; lowest pitched cricket song; often thought to be a frog; loud, clear, rhythmical but not synchronized; in burrows or sometimes on ground at night; day and night.

Gryllotalpa hexadactyla Perty

(9) Similar to last; occurs only in southeast portion of state; a mating song only of this species, more frequently heard in daytime. See A, 2, b, (2), (c).

Scapteriscus acletus Rehn and Hebard (2)

(10) 3 to 5 per second; loud creaky notes; on ground in woods, and on coastal dunes; some singing in daytime, more at night.

Gryllus assimilis Fab.

(11) 3 to 4 per second; high pitched, clear; with constant rhythm; synchronized with others near by; in trees, none observed less than 6 feet from ground; late afternoon and night.

Cyrtoxipha gundlachi columbiana Caudell

(12) 3 to 7 per second, rate variable; with rasping undertone; sometimes in series of 7 to 9 notes with slight drag on last note (mating song); on ground, grass land; day and night.

Nemobius fasciatus socius Scudder

(13) 4 to 8 per second (apparently two forms, one having rate about twice as fast as the other); very high pitched, tinkling notes; on tall grasses, herbs, bushes or vines; day and night.

Anaxipha exigua (Say)

(14) 6 to 8 per second; sharp high pitched chirps, less clear than last; at times about half as fast (mating song); on ground, in pine or oak woodland; day and night.

Nemobius fasciatus tinnulus Fulton

NOTES ON SPECIES OMITTED FROM THE KEY[2]

No species were included in the key whose song is not known to the writer. Most of the species omitted are rare in the state or restricted in distribution.

Limited observations were made on a single caged specimen of the rare *Symmetropleura modesta* Brunner on July 25, 1930. It repeated a short, weak note, with abrupt termination, like "thk-thk," at a somewhat variable rate close to one note per second at a temperature estimated at about 85°F. At first it sang in short series with as few as 7 notes each, but later continued for sometimes as many as 50 notes. Whether it would keep up a continuous repetition under more normal circumstances is still open to question.

The song of the uncommon *Microcentrum retinerve* (Burmeister) has been described by Allard (1) as "several lisping or rasping phrases rapidly delivered, each successive phrase being shortened usually thus: Sh-sh-sh-sh—sh-sh-sh—sh-sh. The usual number is three, although rarely four may be given. In low temperatures only one phrase may be given. This succession of phrases is given at very irregular and infrequent intervals as the creatures are roaming over the crowns of trees, usually not oftener than one to three in a minute."

The large cone-headed grasshopper, *Neoconocephalus exiliscanorus* (Davis), has been found but not heard by the writer. It is an inhabitant of marshy places. The song is described by Rehn and Hebard (3) as a "vibrant rattling note rising and falling in intensity, often ceasing as if from exhaustion." On warm evenings the rate is about 3 per second and each series has from 14 to 26 notes. Allard (1) observed that singers near each other maintain perfect synchronism.

The song of *Neoconocephalus palustris* (Blatchley), an inhabitant of fresh water marshes, is described by Rehn and Hebard (3) as similar to *N. retusus*. Two other species of the same genus probably occur in the

[2] Two species not previously found in the state were found during 1931 in vicinity of Lakeview, N. C. (a) *Nemobius ambitiosus* Scudder: Song would come in key under II, B, 2, b. Notes of calling song about 6 in 10 seconds, weak, moderately clear, with noticeable tremolo, and slightly crescendo. Mating song weaker but faster, 15 to 20 notes in 10 seconds or at times notes are run together making continuous sound for 1 to 5 seconds. (b) *Belocephalus subapterus* Scudder: Song would come in key under I, D. It is a series of moderately loud, distinct rasps too rapid to count. Series lasts one or more seconds and repeated a number of times between longer periods of silence. The song of one generally stimulates others to sing.

state for they have been found both north and south of us. They are *N. melanorhinus* (R & H) and *N. caudellianus* (Davis). The former is confined to salt marshes and the latter is more widely distributed in marshy areas and fields. Rehn and Hebard (3) have described the songs of both species. The song of the former is a continuous buzz similar to *N. robustus crepitans*, but weaker and less harsh. The latter has an intermittent song described as "loud, resonant and constant dzeeeet-dzeeeet-dzeeeet, always the same, not rising and falling, the notes given deliberately, counted as averaging 12 in 10 seconds."

Two other species of Orchelimum, whose songs the writer has not found described, are known to occur in the state. *Orchelium fidicinium* Rehn & Hebard[3] occurs in salt marshes from Long Island to Florida and *O. bradleyi* Rehn & Hebard[3] is a fresh water marsh inhabitant found at Greenfield Pond near Wilmington and southward.

The writer has not heard the songs of five other species of *Conocephalus* known to occur in the state, and no published descriptions of them could be found. Three of these are salt marsh species, namely *aigialus* Rehn & Hebard, *nigropleuroides* (Fox) and *spartinae* (Fox).[3] *Conocephalus strictomerus* Rehn & Hebard has been found in both fresh and brackish marshes. *Conocephalus saltans* (Scudder), a common species in xeric grassland, has very small tegmina and probably has a very weak song. Another species, *C. allardi* (Caudell) has been found in the mountain regions of Virginia and Georgia and probably occurs in North

[3] During 1931 the author observed the songs of several of the above species:

Orchelimum fidicinium: Similar to *O. militare* except that notes are only about ½ second in length. Both species have notes of distinct fluttering quality. In *O. minor* this quality is even more pronounced and in *O. concinnum* it is less distinct but the other members of the genus have a steady buzz in the long notes.

Orchelimum bradleyi: Comes closest to the song of *O. erythrocephalum* but slower and not so loud. Song usually a fairly regular repetition of a brief flutter followed immediately by a crescendo buzz, at a variable rate of 6 to 10 in 10 seconds. At times the preliminary short note is hardly audible and occasionally it may be repeated several times.

Conocephalus aigialus, C. nigropleuroides, and *C. spartinae:* These three species (both sexes) were caged in the laboratory for several days, a few brief songs of the last two were heard. They were very weak like *C. brevipennis* and they did not sing long enough to bring out any characteristic qualities. Apparently they are all poor singers and it is doubtful if they could ever be heard in the salt marsh where much louder singers are abundant.

Atlanticus monticola: Song observed at 55°F. Audible about 30 or 40 feet, a soft rasping sound, each note plainly of 3 wing movements. Notes repeated about two per second when regular, but there are many longer pauses so that the actual rate varies from 10 to 16 in 10 seconds.

Carolina. Its song has been described by Blatchley (2) from notes by Allard as soft, faint, and often greatly prolonged phrases with no short lisping notes.

No descriptions could be found of the song of the three other species of Atlanticus, known to occur in North Carolina, namely, *monticola* Davis,[3] *gibbosus* Scudder, and *americanus* (Saussure).

Only two North Carolina species of crickets having a stridulatory mechanism have been omitted from the key. *Hapithus agitator* Uhler, a common, medium sized cricket has not been heard out of doors by the writer. It apparently seldom sings and the sound is so faint that it is doubtful if it could be heard where other insects are singing. A male caged with a female was once caught in the act of singing while following the female about the cage. Its song was a creaky, fluttering sound, continued for 15 to 25 seconds at a time, so weak that I had to hold one ear close to the top of the jar in which the insects were confined in order to hear it distinctly. The stridulatory vein of a specimen of *Hapithus* examined under a microscope showed only 35 rather widely spaced teeth.

Falcicula hebardi Rehn, the other cricket omitted from the key, is one of our smallest crickets. It has no visible auditory organs on the front tibiae and the stridulatory vein is very small with only about thirty faint cross ridges. It is doubtful if it makes any sound audible to the human ear.

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AT WHAT HOUR IS RAINFALL THE HEAVIEST?[1]

By Lee A. Denson

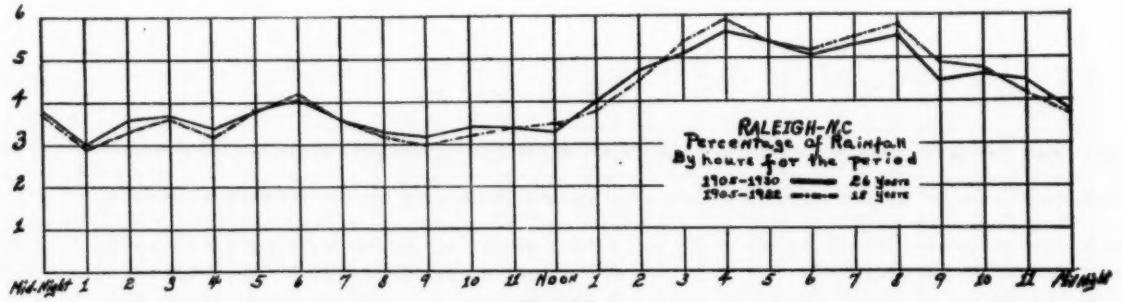
Normals or averages of precipitation have been worked out on records of 50 years or more by the year, month and day, but little is definitely known of the hourly variations in rainfall over any considerable length of time, hence the question at what hour is the rainfall heaviest.

The Weather Bureau has been entering the rainfall in hourly amounts on the daily record for the past 26 years. It is from this record of the Raleigh Station that it is proposed to show the hourly averages for this locality which would be approximately the figures for most of North Carolina as the Raleigh rainfall is a fair average for the piedmont section and the upper coastal plain. The hourly amounts are available only in the daily records, and so in order to find hourly averages it has been necessary to go back over all hours, day by day and hour by hour, for the 26-year period. This is what has been done, the total time covering nearly 228,000 hours.

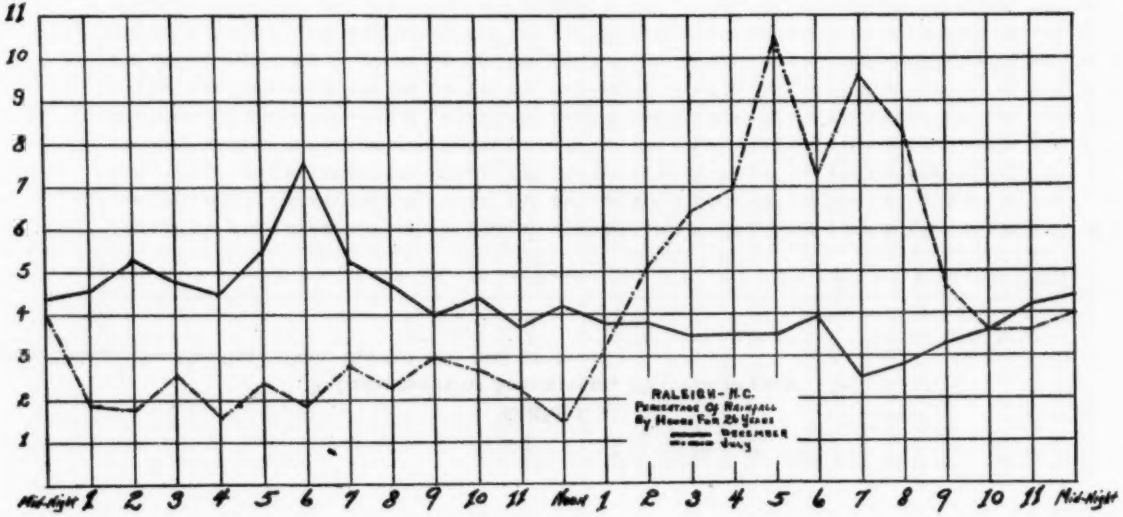
The water equivalent of snow, sleet and hail is given under rainfall. The total precipitation for each of the 24 hours has been worked out beginning with 1905, by months, for 18 years, and then for the entire 26 years to 1930. The hourly amounts are worked out on a percentage basis carried to tenths of one per cent, or in other words to thousandths of the whole sum.

The solid line on graph 1 shows the 26-year period and the dotted line the period of 18 years. The vertical lines show hours as marked and the horizontal lines per cent. Following the solid line it is found that for the year as a whole the heaviest rainfall occurs in the hour ending at 4 p.m. (5.6 per cent). However, the hourly values from 4 p.m. on until 8 p.m. are only slightly less. The least is at 1 a.m. (3 per cent) followed next by 9 a.m. and other later hours of the forenoon. Nearly twice as much rain occurs at 4 p.m. as at 1 a.m. It is also shown that the amount is much heavier in the last than in the first 12 hours, the afternoon showing about 39 per cent increase over the

[1] Published with the approval of the Chief of the Weather Bureau, U. S. Department of Agriculture.


RALEIGH-N.C
Percentage of Rainfall
By hours for the Period
1905-1930 ——— 26 Years
1905-1922 - - - - 18 Years
Mid-Night 1 2 3 4 5 6 7 8 9 10 11 Noon 1 2 3 4 5 6 7 8 9 10 11 Mid-Night

GRAPH 1


RALEIGH-N.C.
Percentage Of Rainfall
By Hours For 26 Years
——— December
- - - - July
Mid-Night 1 2 3 4 5 6 7 8 9 10 11 Noon 1 2 3 4 5 6 7 8 9 10 11 Mid-Night

GRAPH 2

TABLE 1

U. S. DEPARTMENT OF AGRICULTURE, WEATHER BUREAU

Station, Raleigh, No. Carolina. Data, Rainfall 1905–1930 (26 years).

	A.M.												P.M.												TOTAL
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Mid-night	
January	3.25	3.54	4.47	4.08	4.65	4.26	3.70	3.29	3.10	3.55	3.41	3.80	2.93	3.10	2.92	2.84	3.09	3.17	3.39	3.22	4.26	3.47	4.22	4.02	85.73
February	3.06	3.29	3.68	3.69	3.53	4.47	4.54	4.71	4.12	4.29	3.62	4.62	4.90	4.25	3.73	3.72	3.93	4.70	4.08	2.91	3.82	4.25	4.76	3.93	96.60
March	3.32	3.46	4.19	4.82	5.49	5.58	5.32	3.54	4.11	4.13	3.97	3.10	4.01	4.13	3.29	3.69	2.87	2.44	3.39	3.51	3.16	3.60	3.55	3.53	92.20
April	2.33	2.44	1.96	2.29	3.03	3.54	3.89	3.66	3.56	3.82	3.49	4.03	3.38	3.46	4.08	4.90	3.96	3.42	4.85	3.69	4.68	4.44	4.34	3.00	86.84
May	3.33	2.54	4.13	3.45	4.04	3.14	2.61	2.68	2.40	1.93	1.35	2.32	2.70	5.64	4.92	5.60	4.79	5.19	5.55	5.85	4.36	4.01	3.33	3.57	89.43
June	1.95	2.83	2.46	3.78	2.09	2.90	2.38	2.86	1.48	2.67	3.36	3.57	4.94	5.63	4.35	5.06	6.72	6.48	6.74	11.52	9.62	10.15	7.99	4.20	115.73
July	2.49	2.39	3.42	2.17	3.14	2.48	3.65	3.11	3.84	3.51	3.04	1.98	4.16	6.68	8.45	9.01	13.86	9.61	12.70	10.97	6.03	4.77	4.78	5.31	131.55
August	3.66	4.20	3.24	1.71	1.72	5.35	2.89	3.16	4.06	3.62	4.07	3.14	7.66	7.75	11.08	12.33	9.85	9.14	7.51	5.89	4.52	6.66	7.29	4.70	135.20
September	2.75	4.04	3.33	4.29	4.51	3.23	3.59	3.32	2.87	3.40	5.29	3.28	2.90	4.43	8.57	9.96	4.58	5.20	5.24	5.97	3.69	1.52	2.36	2.36	101.31
October	2.24	3.78	4.37	2.19	2.84	2.36	2.23	2.72	1.41	1.35	1.41	2.18	2.99	2.80	2.18	2.24	3.02	4.33	3.13	3.31	3.06	3.43	2.99	3.29	65.85
November	2.22	3.45	2.72	2.69	3.24	2.91	2.35	1.25	1.65	2.40	2.33	1.95	1.95	2.44	1.64	1.87	2.08	1.33	2.22	3.56	1.86	2.30	2.20	2.04	54.65
December	4.32	4.96	4.52	4.19	4.74	7.10	4.94	3.44	3.78	4.10	3.44	3.98	3.61	3.59	3.32	3.27	3.26	3.68	2.43	2.63	3.09	3.41	3.92	4.14	93.86
Sums	34.92	40.92	42.49	39.35	43.62	47.32	42.09	37.74	36.38	38.77	38.78	37.95	46.13	53.90	58.53	64.49	62.01	58.69	61.23	63.03	52.15	52.64	51.73	44.09	1,148.95
Per cent	0.030	0.036	0.037	0.034	0.038	0.041	0.037	0.033	0.032	0.034	0.034	0.033	0.040	0.047	0.051	0.056	0.054	0.051	0.053	0.055	0.045	0.046	0.045	0.038	1.000

forenoon. Another interesting point is that the amount of precipitation from 6 a.m. to 6 p.m. is equal to the amount from 6 p.m. to 6 a.m.

The dotted line is for the 18-year period and is entered to show the same trend; the solid line for the longer period merely shows a slight tendency to straighten the curve.

The records of two of the months, July (dotted) and December (solid) on the second graph are given to show the outstanding difference between the heavy afternoon rains of summer and the relatively heavy rain of the latter half of the night in a winter month. All months from November to March show more rain at night than during the day time. October is also inclined toward the night, but April showers are more equally distributed.

There is not sufficient time to go into the practical side of this matter. One point would be to plan out of door work and sports in the forenoon from May until September and in the afternoon from October to March.

It would be interesting to know how the hourly variations in other parts of the country compare with the Raleigh record, and it is hoped that others will undertake to work out a similar average for the full available record of 26 years, and preserve the results so that the period of time may be lengthened in the years to come.

The difference is slight in the hours between 4 p.m. and 8 p.m. and possibly a longer record may shift the heaviest hour to a later time than 4 p.m.

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THE AQUATIC VEGETATION OF QUAKER RUN[1]

By Velma Dare Matthews

Quaker Run was selected as a typical small mountain stream for the study of plant life in swift water. This stream arises near the New York and Pennsylvania state line at an elevation of about 2300 feet and flows through Cattaraugus County, New York, finally emptying into the Allegheny River near Quaker Bridge, N. Y., at an elevation of about 1200 feet. Dr. Lobeck divides Quaker Run into four sections based on the gradient of the stream. These sections which will be listed below have been followed to some extent in the study of the vegetation, but it has been necessary to subdivide some of the sections for our study. The first section, which extends from the source to within a mile of the dam at the Allegany School of Natural History, has a slope of about 240 feet per mile. (On account of its winding nature the slope is not as great as might be expected from the above figures.) In the second section, extending for a mile above the dam, the slope decreases rapidly so that the average gradient is only about 100 feet per mile. The third section, extending from the dam at the Allegany School to Park Headquarters, a distance of about 3½ miles, has an average gradient of about 100 feet per mile. However, the upper part of the above mentioned section has as gradient of 140 feet per mile. The fourth section, extending from Park Headquarters to the mouth, a distance of about 5 miles, is rather flat and has an average slope of only about 30 feet per mile. From the above mentioned facts, one may easily see that this stream affords a variety of conditions along its course. The vegetation also shows a decided change from the source to the mouth, which will be shown in the discussion of the vegetation of each section.

Streamside Vegetation

The banks of the upper sections are covered with a heavy growth of mosses and liverworts of many kinds. In the lower sections, mosses and liverworts are less abundant and lacking on the sunny exposed banks of

[1] Contribution from The Allegany School of Natural History. This study was supported in part by a grant from the Rockefeller Fund.

the lower part. Willows, maples and beech are the predominating trees along the bank. No special study has been made of these forms. House and Alexander in their *Flora of the Allegany State Park* have listed the principal flowering plants which are found along the banks of Quaker Run.

AQUATIC VEGETATION

SECTION ONE

Near its source Quaker Run is a very small, winding stream, which disappears underground at intervals to reappear several feet farther down as a stream several feet in width. Frequently it is completely hidden by the heavy growth of grasses and shrubs along the bank. Practically the entire upper section is constantly in deep shade due to the presence of numerous branches from the many trees along the bank. The gradient is so high that in many places the water is swift but there are numerous places where the water flows slowly, due to the character of the bed or to the many obstructions made by logs which have fallen across the stream or directly into it. Large moss-covered logs 40 or 50 feet in length may be found in the center of the stream. For the first several hundred yards the banks are covered with a heavy growth of *Sphagnum*, which in some cases grows in the flowing water. Intermingled with the *Sphagnum* and floating in the slowly moving water, the desmid *Gonatozygon* was found in large quantities. This plant was so abundant that it formed a thin green blanket over the surface for a distance of about ten feet, which reminded one of a mass of *Spirogyra*. Mixed with this desmid were some other unidentified desmids. About a fourth of a mile below this place a second mass of *Gonatozygon* was found intermingled with large tufts of *Fontinalis dalecarlica* B. & S. It was so abundant that it gave a bright green color to the water in a very shady place. An occasional diatom and a very few strands of another filamentous desmid were found in this collection. *Gonatozygon* seems to prefer a high altitude, as it was not found in any other part of the stream. However, it may appear in the lower sections at other seasons of the year.

A short distance down the stream liverworts and mosses grow very luxuriantly. The majority of the small rocks, many of which are submerged, are covered with the leafy liverwort, *Scapania undulata* (L.) Dumort, which often reaches a length of two inches. A second leafy liverwort, *Calypogeia tenuis* (Aust.) Evans, was found covering wet rocks and logs in very shady places. This plant has been observed in

Quaker Run only in the upper section. It was also found to be abundant on rocks in a small swift mountain stream near its source located at Heart's Content, Pennsylvania. In a few places the dainty, minute liverwort, *Cephalozia bicuspidata* (L.) Dumort, was found covering wet rocks and logs. This seems to be the only region in the stream where this species grows. Small clumps of *Pellia epiphylla* (L.) Corda were found growing in the bed of the stream in at least a half dozen places. These plants were large and showed the involucres near the apex in August.

The most conspicuous plants in the stream are the mosses of various species. The linear leaved water moss, *Fontinalis dalecarlica*, grows in large tufts often over a foot in length attached to the stream bed, rocks and logs. In a number of places these tufts are so numerous that they completely cover the bed of the stream. In swift places mats of *Hygrohypnum ochraceum* (Turn.) Loeske often grow intermingled with the *Fontinalis*. The former species also grows in small mats on some of the rocks, but it is never abundant in this section. Along the banks and covering twigs and some rocks in the stream are heavy mats of the light green moss, *Mnium hornum* L. Occasionally this species and *Catharinea undulata* (L.) W. & M. were found growing completely submerged. The submerged plants had smaller leaves and the leaves were farther apart on the stem than those of the plants which were growing on the bank and on wet rocks in the stream. *Hygrohypnum dilatatum* (Wils.) Loeske undergoes a similar change when it grows submerged. The large leaved *Mnium, Mnium punctatum* var. *elatum* Schimp., grows on wet rocks in the stream and attached to the soil along the edge. In a few cases *Mnium rostratum* Schrad. was growing intermingled with *Hygrohypnum* and other mosses. Two additional mosses found attached to the stream bed are *Plagiothecium elegans* (Hook.) Sulliv. and *Plagiothecium denticulatum* (L.) B. & S. *Plagiothecium elegans* forms mats several inches wide but only a few plants of *P. denticulatum* were collected.

In the lower part of the first section plants are less abundant, but *Scapania undulata, Mnium hornum, Hygrohypnum ochraceum* and *Fontinalis dalecarlica* are present in noticeable quantities.

SECTION TWO

In the second section, Quaker Run is wider, and although the gradient is only about 100 feet per mile, there are numerous small waterfalls and the stream is often very rapid. Obstructions are less numerous than in

section one, but fallen twigs and logs often slow up the rate of the current and cause the formation of small pools. The overhanging boughs of the trees along the bank cut off the rays of the sun from most of the stream but there are portions at intervals where the sun reaches it. On the average, more light is available than in the upper section. Algae are never abundant but are found in small quantities on some of the rocks and in quiet pools along the edge. In a shallow pool just below a large log about one-half a mile above the dam, the bed was covered with large masses of the blue-green alga, *Oscillatoria*. A few desmids belonging to the genera *Closterium* and *Cosmarium* and many diatoms most of which were *Navicula* and *Surirella* were growing intermingled with the *Oscillatoria*. Some of the rocks in swift water in open places are covered with the blue-gree algae *Desmonema* and *Lynbya*. A few patches of the bright green alga *Stigeoclonium* are present on the rocks in swift water. A sterile form of *Vaucheria*, a few strands of *Mougeotia* and *Hormidium*, and a few strands of the red alga *Bangia atropurpurea* (Dillw.) Ag. were collected from rocks in swift water. Mixed with this collection was some of the diatom, *Diatoma*.

Liverworts grow on the rocks usually in the shade or in partial shade and either in the rapid or slow water. *Pellia epiphylla* occurs on wet rocks along with *Hygrohypnum*. *Scapania undulata*, which is so abundant in section one, is found on the rocks above and below the water line, but never in large quantities. Here the leafy liverwort, *Chiloscyphus fragilis* (Roth.) Schiffn. is the most abundant plant of this type. *Chiloscyphus fragilis* is often found on rocks in small waterfalls and covers many rocks along the edge especially in very shady shallow places. The large upright liverwort, *Plagiochila asplenioides* (L.) Dumort., which resembles the Mniums, covers a few rocks in the central part of this section.

A few tufts of *Fontinalis dalecarlica* grow in the upper part. In the central part another species of *Fontinalis*, *F. Novae-Angliae* Sulliv. grows attached to twigs, stones and the bed of the stream. It is found only in scattered tufts. In the lower fourth of the section the giant water moss, *Fontinalis gigantea* Sulliv. forms large floating masses, which may be up to two feet in length and attached to rocks or twigs. This species is especially abundant in a small stream which enters Quaker Run near this place. Scattered all along this section on rocks in the shade or in the sun, in the rapids and in slowly moving water is found the small moss *Fissidens incurvus* Schwaegr. The leaves of this moss are arranged in two rows and the plants are usually less than 4

mm. in length. Large wet rocks in the shade and in waterfalls are covered with mats of the yellow-green, *Hygrohypnum ochraceum*. Mixed with this species and in tufts on a few other rocks are *Hygrohypnum dilatatum* and *Eurhynchium rusciforme* (Neck.) Milde. A few rocks in the water are covered with the small dark green moss, *Amblystegium irriguum* (Wils.) B. & S. *Mnium punctatum* L. and *M. rostratum* are found in small quantities mixed with *Hygrohypnum*. In a few places *Mnium punctatum* var. *elatum* grows in the water along the edge where the current is not swift.

Callitriche heterophylla was found in a sunny place where the water was very swift. This is the only flowering plant which was found growing in swift water in Quaker Run. However, *Heteranthera dubia* (Jacq.) MacM. grows in very swift water attached to rocks in the Allegheny River near the entrance of Quaker Run

SECTION THREE

It seems best for our purpose to subdivide this section. Part *A* will extend from the dam at the Allegany School of Natural History to about ¼ of a mile below Camp Turner, a distance of about 2 miles. This section has a gradient of about 140 feet per mile. Part *B* will extend from Part *A* to Park Headquarters, a distance of about two miles. The gradient here is less than 100 feet a mile.

Part A

Small waterfalls and large moss-covered rocks are abundant in this section. There is shade along the edge but in many places the center of the stream is in direct sunlight for at least a part of the day. Immediately below the dam there is an open space where the bed is filled with small rocks. On each side in still water the water is covered with a heavy growth of the iron bacteria, *Leptothrix* and *Didymohelix*. There are several other places in this section and in the lower part of Quaker Run where many small rocks and the surface of the water are covered with these bacteria.

Algae of many different species were found attached to rocks, to twigs, floating and associated with mats of water mosses. Three genera of red algae are represented in this area. *Chantransia* and *Bangia atropurpurea* were found in a collection of moss and algae from a rock in swift water. Perhaps the most interesting alga in the stream is the large red alga, *Tuomeya grande* Wolle, which is found on rocks in the swift water throughout this area. A few small tufts were found

on the rocks near the Allegany School and in small quantities down to the entrance of Jaeger's Run. From this place to the end of the section, *Tuomeya* is very abundant, often entirely covering large rocks. A tuft often contains 20 stalks, which may reach a length of two inches. In some sections the plants are very small being only about ½ an inch in length. These tufts of *Tuomeya* often collect detritus and mixed with this or attached directly to the stalk one may find such algae as *Ulothrix* and diatoms such as *Melosira* and *Navicula* in large quantities. Needham and Strausbaugh report that *Tuomeya* is abundant in the Cacapon River in Hardy County, West Virginia.

The filamentous algae which are found growing on rocks especially in the sun in swift or flowing water are *Mougeotia, Oedogonium, Spirogyra, Stigeoclonium, Ulothrix* and *Zygnema. Spirogyra* and *Stigeoclonium* form bright green patches on a few rocks but are never so abundant as in Part *B*. Attached to the rocks, twigs or floating in still or slowly flowing water along the edge are *Vaucheria geminata* D. C., *Vaucheria aversa* Hass., *Spirogyra* (two species, one very slender form with a single chloroplast and a large form with many chloroplasts), *Draparnaldia, Mougeotia,* and *Zygnema.* Many plants of the epiphytic green alga, *Characium Naegelii,* were growing attached to filaments of *Oedogonium* on rocks in flowing water.

Collections made of the coatings of rocks in flowing water revealed the presence of many desmids of the genera *Closterium, Cosmarium,* and *Roya.* Intermingled with the desmids were numerous diatoms some of which were as follows: *Melosira varians, Denticula, Amphora, Meridion, Navicula, Synedra, Gomphonema* and *Diatoma.*

Blue-green algae often cover rocks in places exposed to the sun giving them a blue-green or brown color. *Phormidium, Lynbya,* and *Oscillatoria* are the genera mainly responsible for these slimy films over the rocks. Occasionally large masses of brown jelly are found attached to the rocks in swift water. These are colonies of *Nostoc* embedded in a tough jelly.

Scapania undulata is found in small groups on rocks throughout this section but it is never abundant and the plants are small. *Chiloscyphus fragilis* often grows on rocks in the rapids just below the water line and covers stones in shallow water.

Just below the dam many of the small rocks in the open are partially covered with small clumps of the mosses, *Hygrohypnum ochraceum, Rhacomitrium aciculare,* and *Bryum bimum. Fissidens incurvus* also grows on the rocks throughout this section. A short distance down the

stream in the shade the rocks over which the water dashes at a rapid rate are covered with large mats of moss. Some of these mats are of *Hygrohypnum ochraceum* and others of *Amblystegium irriguum*. *Eurhynchium rusciforme* and *Hygrohypnum dilatatum* are also found here but never in such abundance as the two above mentioned species. *Hygrohypnum ochraceum* and *A. irriguum* are the most conspicuous plants in the first mile of this section. *Bryum bimum* grows in small tufts on wet rocks covered with *Hygrohypnum*, and *Brachythecium reflexum* was found intermingled with *H. ochraceum* on one large rock. It is probably present in other places but we have failed to collect it. Below the entrance of Jaeger's Run there is some change in the moss flora. Here *Eurhynchium rusciforme* covers many submerged rocks in flowing water and many of those in the waterfalls. *Hygrohypnum ochraceum* is still abundant but *Amblystegium irriguum* occurs on only a few rocks. *Hygrohypnum dilatatum* grows on rocks along with *H. ochraceum*. A third species of *Hygrohypnum*, *H. Mackayi* (Schimp.) Loeske, grows closely appressed to some of the rocks. Near Camp Turner *Fontinalis Novae-Angliae* was found attached to rocks. Quaker Run immediately below Camp Turner is filled with many large moss-covered rocks over which the water rushes. Here, *Eurhynchium rusciforme* is the predominant plant. *Hygrohypnum ochraceum*, *H. dilatatum*, and *Amblystegium irriguum* are also numerous in this place. A few plants of *Porotrichum Allegheniense* were collected on a wet rock. On rocks several inches under waterfalls *Hygrohypnum dilatatum* was found in large masses. These plants are very different in appearance from those found growing on wet rocks in waterfalls where there was an abundance of light. The leaves are very small and far apart on the stem.

Part B

The stream in this part is more open, less swift and large moss-covered rocks fewer than in Part *A*. *Tuomeya* was found only on widely separated rocks but the plants are all very small. Many rocks are covered with blue-green algae, which form a coating blue-green, brownish or black in color. *Nostoc* colonies form large balls of jelly on the rocks. Collections made from the rocks in flowing water revealed large numbers of *Navicula* and desmids such as *Closterium*. In a few pools along the edge *Spirogyra* and *Mougeotia* are abundant. *Spirogyra* also forms bright green patches on many of the rocks. In the region of the Buffalo Camps many of the rocks in swift water are covered with

long tufts of *Stigeoclonium*. This alga is much more abundant and grows longer here than in any other section of Quaker Run. These tufts often remind one of *Cladophora*, which is abundant in the Allegheny River but has not been collected in Quaker Run. A few plants of *Draparnaldia* were collected growing attached to small twigs.

A small amount of *Scapania undulata*, a few clumps of *Pellia* and *Chiloscyphus fragilis* grow on the rocks in the shade.

Wet rocks in the shade and in waterfalls are covered with *Hygrohypnum ochraceum*, *H. dilatatum*, *Eurhynchium rusciforme* and *Amblystegium irriguum* with a few tufts of *Bryum bimum* and *Rhacomitrium aciculare*.

SECTION FOUR

This section has also been divided into two parts. Part *A* extends from Park Headquarters about two miles down stream and Part *B* extends from Part *A* to the mouth of Quaker Run.

Part A

Part *A* is very similar in many respects to Part *A* of Section Three. A small amount of *Batrachospermum moniliforme* Roth. was found attached to a rock in swift water growing with *Spirogyra*. This is the only collection of *Batrachospermum* from Quaker Run. However, this species grows in tufts several inches long attached to rocks immediately below the spring at Hermit Springs, Pennsylvania. *Tuomeya* is rare and the specimens observed in most of this area were very small. However, it is very abundant on three or four rocks in the lower portion of this part. *Spirogyra*, *Sirogonium*, *Stigeoclonium* and *Oedogonium* were collected from rocks in flowing water. *Stigeoclonium* and *Spirogyra* are especially abundant in swift shallow water in the central part. *Mougeotia*, *Spirogyra*, *Microspora* and *Zygnema* were collected floating or attached to small twigs in slowly flowing water and in small pools along the edge. Scrapings from rocks and collections of filamentous algae yielded the following kinds of desmids: *Penium*, *Ankistrodesmus*, *Hyalotheca*, *Netrium* and *Closterium*. Mixed with the above were numerous diatoms especially those belonging to the genera *Tabellaria*, *Fragillaria*, and *Navicula*.

The same liverworts represented in section three are present in this area. *Pellia epiphylla* and *Scapania undulata* occur on the rocks in small quantities while *Chiloscyphus fragilis* covers small rocks in the shade. A very small leafy liverwort, *Jungermannia pumila* With. covers a few rocks in the shade.

Rocks in the shade and in waterfalls are covered with mats of *Hygrohypnum ochraceum* and *Amblystegium irriguum* in the majority of cases. Other species found growing in similar places are *Hygrohypnum dilatatum, Eurhynchium rusciforme, Rhacomitrium aciculare* and *Bryum bimum. Fissidens incurvus* is also present on many of the rocks as in the upper sections. Two species of *Fontinalis, F. Novae-Angliae* and *F. gigantea,* are rarely found in small quantities.

Part B

The lower portion of Quaker Run is winding and slow with numerous pools several feet in depth. Much of it is in the open so that wet moss-covered rocks are very rare. Most of the vegetation is attached to small rocks in shallow water. These rocks usually exhibit a flocculent covering made up of detritus, a few filamentous algae, desmids and diatoms. The lists given below of the plants identified in a small amount of scrapings from single rocks at intervals of about ½ a mile will give an idea of the vegetation found on the rocks:

Rock No. 1 (Near Cain Hollow)

Stigeoclonium	*Cosmarium*
Mougeotia	*Closterium*
Spirogyra	*Amphora*
Oedogonium	*Navicula*
Netrium	*Gomphonema*
Scenedesmus	*Anabaena*

Rock No. 2 (½ mile below Cain Hollow)

Mougeotia	*Navicula*
Closterium	*Tabellaria*
Scenedesmus	*Amphora*
Synedra	*Anabaena*

Rock No. 3 (1½ miles below Cain Hollow)

Mougeotia	*Tabellaria*
Cosmarium	*Amphora*
Scenedesmus	*Navicula*

Spirogyra and *Stigeoclonium* form bright green masses on the rocks in the lower part of Quaker Run. In this region *Ulothrix* and *Mougeotia* are found on the rocks in the slowly flowing water. Also in this region *Bulbochaete* was collected on rocks and attached to twigs. Many large rocks are covered with mats of the blue-green algae *Oscillatoria* and *Rivularia.* Other algae collected here not mentioned above are *Euas-*

trum, Spondylosium, Netrium, Pediastrum and *Nodularia.* Near the mouth floating in a pool and attached to twigs and to a log there were large masses of *Oscillatoria* and *Arthrospira.*

No liverworts were observed in this section and only rarely a small rock was found covered with *Hygrohypnum.*

In one place there is considerable backwater where *Ludvigia* is abundant. No study was made of this area.

The field work for this paper was done during July and August and the laboratory work was done in the Laboratory of the Allegany School of Natural History and the Botanical Laboratory of the Unviersity of North Carolina. It is a pleasure to acknowledge indebtedness to Dr. R. E. Coker, the Director of the Allegany School, for suggesting this work and assisting in every way possible in carrying it out. The writer also wishes to thank Dr. W. C. Coker for suggestions.

SUMMARY

1. A study has been made of the aquatic vegetation of a typical small mountain stream, Quaker Run, located in New York State.

2. Mosses and liverworts are more abundant in shade or partial shade than in direct sunlight.

3. Desmids, diatoms and filamentous green and blue-green algae are the predominant plants in the direct sunlight.

4. Diatoms are represented mostly by the genera: *Diatoma, Gomphonema, Melosira, Fragillaria, Amphora, Synedra, Navicula, Tabellaria, Meridion, Denticula* and *Surirella.*

5. The majority of desmids collected belong to the following genera: *Closterium, Ankistrodesmus, Netrium, Hyalotheca, Gonatozygon, Cosmarium, Roya, Spondylosium, Scenedesmus,* and *Pediastrum.*

6. The filamentous green algae which were identified are: *Spirogyra, Oedogonium, Ulothrix, Stigeoclonium, Mougeotia, Zygnema, Microspora, Sirogonium, Draparnaldia, Vaucheria* and *Bulbochaete.*

7. Four genera of red algae *Batrachospermum, Chantransia, Bangia* and *Tuomeya* grow in Quaker Run.

8. Seven species of liverworts were collected: *Pellia epiphylla, Chiloscyphus fragilis, Scapania undulata, Calypogeia tenuis, Cephalozia bicuspidata, Jungermannia pumila* and *Plagiochila asplenioides.*

9. The moss flora was represented by the following species: *Sphagnum* sp., *Fissidens incurvus, Catharinea undulata, Mnium punctatum, M. punctatum* var. *elatum, M. rostratum, M. hornum, Fontinalis gigantea, F. dalecarlica, F. Novae-Angliae, Hygrohypnum Mackayi, H. dilatatum,*

H. ochraceum, Amblystegium irriguum, Rhacomitrium aciculare, Eurhynchium rusciforme, Brachythecium rutabulum, B. reflexum, Plagiothecium elegans, P. denticulatum and *Porotrichum Allegheniense.*

10. The flowering plant, *Callitriche heterophylla* was found growing in swift water.

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MAYFLIES OF NORTH CAROLINA

By Jay R. Traver[1]

Plates 5–12

I. Introduction

The state of North Carolina, with its several distinct life zones, might well be expected to offer as rich a field to the collector of insects as to the systematic botanist. The results of collecting and rearing representatives of that interesting group of insects, the Ephemerida or mayflies, in this state during the years of 1928–30 show that this expectation is fully justified. Twenty-seven genera, two of them new, are represented in the material collected. More than one hundred different species have been taken here, approximately one-third of which have not been previously described. The account of the collecting and rearing of these insects, with certain observations on their habits, occupies the second and third part of this thesis. The fourth part, being purely systematic, is devoted to a presentation of the genera and species found, together with descriptions of the two new genera and the new species.

Geographic divisions and life zones.

The three geographical divisions of the state of North Carolina accord practically with the three main life zones. Thus the coastal plain, extending inland about 125 miles, is in the Lower Austral Zone, except a narrow area south from Wilmington which is in the Gulf Strip. From the inner edge of the sandhills to the foothills of the Blue Ridge is the piedmont region, in the Upper Austral Zone. The remainder of the state, westward from the Blue Ridge to the crest of the Great Smokies, is known as the Appalachian region. Most of this is in the Transition Zone, save for the tops of the higher mountains. Here is found the Canadian Zone, ranging upward from about 4500 ft.

The relatively flat coastal plain or tidewater region is contrasted sharply with the other regions of the state. Deeply indented on its

[1] Contribution from the Limnological Laboratory of Cornell University.

seaward side by many bays and sounds, it extends from the banks at the seashore to the sandhills on the eastern borderline of the piedmont. The soil here is mainly a sandy loam, and there are many dark-water streams. Large swamps are numerous, and many good-sized natural lakes, most of them filled with the characteristic black water of the region.

The piedmont varies from relatively low country next to the coastal plain, with an elevation of 200 to 500 ft., to a plateau on the western border, attaining there an elevation of 1200 to 1500 ft. Interrupted chains of weather-worn mountains, the rocks composing them of Pre-Cambrian age, are scattered through the piedmont. Along its eastern and northern borders, the Uharie Mts. appear, often merely as hills somewhat higher than the surrounding country. Isolated areas of higher chains occur in the north and west,—the Sauratown, Brushy and Pilot Mts. The latter chains are often considered foot-hills of the Blue Ridge. The orange to reddish brown clay loam of the piedmont has resulted from slow erosion of the very ancient underlying rocks.

The Appalachian region is a high plateau, bounded on the east by the escarpment of the Blue Ridge, and on the west by the Great Smokies. Many lesser mountain chains running crosswise between these two great ridges divide the plateau into valleys and heights. Included in this region is Mt. Mitchell in the Black Mts., the highest peak east of the Rockies, with an elevation of 6711 ft. Several peaks in the Great Smokies lack but a few feet of attaining the height of Mt. Mitchell. The Great Smoky National Park lies in part within this region, on the Carolina-Tennessee border. The Pisgah, Unaka, Nantahala, and Cherokee National Forests are included within its borders. The orange-red soil found on the lower levels is closely allied to that of the piedmont, in appearance and derivation. A dark acidic humus is found on many of the higher mountains. These mountains, probably of Paleozoic age, are very similar in age and composition to the rocks underlying the piedmont and cropping out as low mountain chains there.

Drainage basins

The drainage basins of the state may be divided into (1) the streams draining into the Atlantic directly, and (2), those whose waters first enter the Gulf of Mexico. The Blue Ridge is the main watershed.

The first group is subdivided into those streams which run to the ocean within the borders of the state, and those which reach it only after

transversing South Carolina and Georgia. The principal rivers of the first division are, from north to south, the Chowan, the Roanoke, the Pamlico or Tar, the Neuse and the Cape Fear. The last three derive their waters from North Carolina alone. In the second division belong the Yadkin, which on crossing the line into South Carolina becomes the PeeDee; the Catawba, which becomes the Wateree, joining the Congaree in South Carolina to form the Santee; and the Rocky, First and Second Broad Rivers, uniting to form the Congaree. All of these rivers have their headwaters in the eastern foothills of the Blue Ridge, and flow southward, cutting gorges as they cross the line of the Uharie Mts.

Only one river arising east of the Blue Ridge fails to flow directly into the Atlantic Ocean. This is the New, which flows northward to join the Ohio. Several large rivers arise on the western slopes of the Blue Ridge and flow westward, receiving tributaries from the lesser mountain chains and from the eastern slope of the Great Smokies. These rivers cut deep gorges through the lofty ridge of the Great Smokies and join the Tennessee or its branches to the west of this great mountain wall. From north to south these are the Nolichucky; the Watauga; the French Broad; the Pigeon; the Little Tennessee, with its large tributaries, the Ocona Lufty, the Tuckaseegee, the Cullasaja and the Nantahala; and in the extreme southwest the Hiwassee.

There are no natural lakes of any size in either the piedmont or the Appalachian regions, but many lakes have been formed artificially, particularly in the latter area. The rivers flowing east and south through the piedmont accomplish their main fall before reaching the eastern boundary of the piedmont, so that little real fall occurs at the so-called fall line. Yet in many of these rivers a fair current is in evidence up to within a few miles from the ocean.

When and where collections were made

During the fall of 1928 and the spring of 1929, collecting was done in the piedmont area only. My headquarters being at Greensboro, trips were made in all directions from this point as a center. The summers of 1929 and 1930 were spent in the Appalachian region. In 1929 my headquarters were at Black Mt., Franklin, and Waynesville. In 1930, the central points for collection were Swannanoa and Penrose. The fall of 1929 and the spring of 1930 were again devoted to collecting in the piedmont, except for a short trip to the eastern coast in April, on which trip some collecting was accomplished in the coastal plain.

In addition to my own collecting in the state, Prof. J. G. Needham has kindly turned over to me many specimens which he collected in the spring of 1929, some from each of the three major divisions of the state. Some specimens were also received from Dr. J. S. Gutsell of the Bureau of Fisheries at Beaufort, taken from the Appalachian region near the town of Sylva.

Collections are at hand from sixteen stations in the coastal plain, thirty-eight stations in the piedmont, and seventy stations in the Appalachian region.

As yet, material from the coastal plain is very limited, and much needs yet to be done in this area before any comprehensive idea can be obtained of its mayfly fauna. The piedmont and Appalachian regions have been worked more thoroughly, yet even here there are many areas in which no adequate collecting has been done. While the present work is far from complete, it is hoped that it may serve to broaden our knowledge of the Ephemerida within the boundaries of North Carolina, and lay the foundation for more extensive studies in the future.

Historical

Previous to this time, reports of mayflies from this state have been very few, and have been related mainly to small areas in the Appalachian region. Eaton, in the *Revisional Monograph*, listed but four species of mayflies that had been reported from North Carolina. These are: *Hexagenia munda* Etn., described from a male imago taken near Morganton, N. C.; *Blasturus cupidus* Say, (listed as variety from N. C.); *Isonychia sicca* Walsh; and *Heptagenia interpunctata* Say. Banks, in 1908, listed from North Carolina a new species of Leptophlebia, *Siphlonurus mirus* Etn.; and *Heptagenia vicaria* Wlk.; as well as two species listed by Eaton. In 1914, Banks described five species from the Black Mts. of North Carolina. One of these, *Habrophlebia jocosa*, proved to be synonymous with *Habrophlebia vibrans* Needham, while his *Ephemerella vernalis* is stated by McDunnough to be synonymous with *Ephemerella rotunda* Morgan. The three new species are *Leptophlebia assimilis* Bks., *Heptagenia subaequalis* Bks., and *Heptagenia carolina* Bks. In 1924, he described another new species from the same locality, *Pseudocloeon carolina* Bks. McDunnough, 1931, added *Ephemerella dorothea* Needham to the list. As far as I have been able to determine, the foregoing are the only species of mayflies thus far listed as occurring in North Carolina.

II. METHODS

Collecting

In the majority of smaller streams, 'hand-picking' was found to be preferable to other methods of collecting. If a stone is lifted gently from the water and quickly turned over, many mayfly nymphs will remain on it. Species of a few genera, notably Isonychia and Ameletus, can rarely be taken in this fashion, as they leap back into the water with the quickness of minnows. On the contrary, nymphs of Rhithrogena have not been obtained in any numbers by any other means. If a net or dish, or the hand of the collector, be held beneath the stone as it is lifted and turned, any nymphs that let go their hold on the stone and fall off may be caught before they reach the water. Some individuals will have been washed off before the stone can be removed from the water.

Collecting with the hand-screen and rake was most successful in rapid water and in larger streams where the water was quite deep. For this method of collecting, it is well to have a helper, who lifts the stones with the rake while the screen is held in the current below. It can be manipulated by one person if necessary, however. Rhithrogena was seldom taken by this method, but specimens of most of the other genera could be thus obtained. Baetisca was never taken by hand-picking; all but two of the specimens of this genus caught were taken with the hand-screen. In all streams in which the hand-screen was used, hand-picking was likewise employed in part or all of the same areas.

Wherever pondweeds or other aquatic plants grow, a net is essential for sweeping up the nymphs which normally cling to the stems and leaves. A stick or the handle of the net may be used to brush the plants and cause the nymphs to swim free, after which frequent sweepings of the net through the water catch many of those that were dislodged.

Isonychia may often be caught in the hand, for all its activity as a jumper, if a shallow portion of the stream is located in which many nymphs are congregated between and under small stones. A net is useful if the water is not too shallow. Many stones are removed until a small pocket with sand or gravel bottom is formed, in or near which the nymphs collect. They may then be scooped up by the use of both hands.

For collecting burrowing nymphs, some apparatus such as Prof. Needham's sieve net is most useful. This net sifts the mud and silt, retaining all the nymphs. In shallow water, the mud may be scooped

up with a large spoon or other implement of a similar nature, or by hand, and spread out on the bank or the tops of large flat stones. As the water seeps away, the nymphs begin to scramble out, and may be readily located.

Transporting nymphs

In cool weather, nymphs may be placed as caught in glass fruit jars or other containers supplied with a lid. For the homeward journey, the lids must be securely clamped or screwed on to prevent the spilling of the water and the escape of the nymphs. This method is very undesirable, however, for hot weather, for all forms of nymphs that live normally in rapid water, or when the collecting is done in streams many miles from where the nymphs are to be reared. The best success in transporting nymphs has been obtained in this fashion. As the nymphs are taken from the stream, they are placed at once in wire rearing cages of the pillow type, as described in Prof. Needham's *Guide to the Study of Fresh Water Biology*. The cages are kept in the stream until the catch is complete. When ready to return home, the top of the cage is closed, and the cages are placed in a pail one-quarter filled with stream water. If a long journey must be made, or the day is very hot, the water in the pail should be changed every few miles.

Rearing the nymphs

In cool weather, the great majority of nymphs may be successfully reared if placed in shallow water in open dishes, such as petri dishes, or half of an evaporating dish, or porcelain pans. The dishes must then be placed where a draught of air continually blows over the surface of the water, as on a window sill. A well-screened window must be chosen if the nymphs are free in the pans, lest the subimagoes escape on emerging. If the nymphs are to be reared in the wire cages, deeper water must be used, and the container for the cage placed in the window. The nymphs should in any case be provided with a few stones, preferably flattened ones, from their native stream. Select stones well overgrown with diatoms, to provide food for any immature nymphs. Submerged leaves or bur-reed stems may be used for all pond forms. This method has at least one great advantage over the one following. The habits, actions and activities of the nymphs may be studied at leisure, even to selecting individual nymphs for close observation.

Probably the easiest and hence the best way to rear nymphs—but a method which it is not always possible to follow, for lack of equipment—is to have shallow troughs into which untreated stream water flows continually at one end, its height in the trough being regulated by an overflow at the opposite end. Into this trough the cages containing the nymphs may be set immediately on the return from the collecting trip. A trip to the cages once a day thereafter, to remove dead individuals and subimagoes, is all that is necessary.

Leaving the cages in the stream where the nymphs were caught, or transporting them to another stream nearer the headquarters of the collector, may sometimes have to be resorted to. Small boys, curious cows, large spiders, and especially sudden and violent thunder storms, prove disastrous very frequently, however, when such methods are employed. The work of several weeks may be swept away or so badly washed as to kill most of the nymphs, in one such sudden storm.

Rearing the subimagoes

When a nymph transforms into a subimago, its nymphal skin should be located if possible, removed from the container and placed in a correctly-labelled vial of alcohol. The subimago must now be kept until its becomes an imago. The methods which have proved most successful in my work in North Carolina are as follows. In the first method, pint glass fruit jars are used. A piece of cloth is cut the exact size of the floor of the jar inside, and inserted. Next a twig is placed in the jar for the subimago to climb upon. A leaf or stem of some succulent plant is placed in each jar before the insect is put into it. The top of the jar is covered with loosely woven cloth held in place by an elastic band. Several subimagoes of the same species may be kept in each jar, which is now correctly labelled and set in a cool dark place. If the weather is hot, the leaves should be changed for fresh ones every twenty-four hours. The chief difficulty experienced in rearing the subimagoes is their failure to cast off the subimaginal skin. This seems to result from too little moisture or too much heat, or both. Hence the leaves in the jars. But too much moisture,—enough to dampen the wings of the insects,—is equally fatal.

A second method sometimes employed was to place a small branch with fresh green leaves inside a pillow cage, put the subimagoes in this cage, and after closing it carefully, put the cage in a cool moist place.

Preserving the specimens

All mayflies, whether nymphs, subimagoes or imagoes, are best preserved in 75 to 80 percent alcohol. Four-drachm vials have been found to be the most useful size. If pinned and dried, the winged forms soon lose legs, tails, even wings,—and the genitalia become so shrivelled as to make recognition of the species difficult. The only possible advantage in dry-pinning is that the colors are better preserved thus.

Labels should be inside the vials, preferably written or printed in soft pencil. Data includes place and date of capture or of emergence, and genus and species if known.

As mentioned previously, the last nymphal skin is removed and placed in a separate vial. If the hour of emergence of the nymph is known, add this to the data. When the subimago has transformed, place the imago and the subimaginal skin in the vial with the last nymphal skin, adding to your data hour of final transformation if known. Such a collection, of the imago and its two exuviae, constitutes a so-called 'life-history.' Data on the exact hour of transformation of nymph to subimago, and of subimago to imago, may well be kept as separate records, and the length of the subimaginal stage recorded when the transformation is complete.

III. Ecological

Habits of the nymphs

Aside from certain brief notes regarding the habits and habitats of nymphs which are included in the accounts of the different species, a few general statements as to habits of nymphs may be presented here. Some of these are based on observations made in the field, when the nymphs were in their native habitat; others on closer observations of nymphs kept indoors in the open dishes or in wire cages.

1. Subfamily EPHEMERINAE

Potamanthus—Nymphs were taken from the sand and fine gravel beneath and in the lee of large stones in midstream, in water not exceeding a foot in depth.

Ephemera—Found burrowing in soft black mud along the banks of streams. Usually in mud an inch or two in depth only.

Hexagenia—In deeper mud near the shores of a large river. In a large pond from which the imagoes were collected, no nymphs were ever found near shore.

2. Subfamily BAETINAE

Baetisca—The peculiar swimming habits of this nymph have been described by Walsh (Proc. Ent. Soc. Phil. 1864, pp. 205–6.). In the glass dish in which my specimens were reared indoors, they often moved from one stone to another. Usually each swam about for a time, often bumping the head repeatedly against the sides of the dish, before settling down again on another stone. During the day they were less active than at night. If turned on its back, a nymph had some difficulty in righting itself. They were readily reared in quiet water indoors. It was soon found that tap water did not injure them, if a little was added each day to the creek water in which they were at first kept.

They feign death when lifted from the water. If the rock on which they are resting is taken from the water, some loosen their hold and fall back immediately, others cling tightly to the rock. In the field, none of these nymphs were ever taken by hand-picking, however, except two that were seen swimming across a quiet pool.

For a period of twenty-four to forty-eight hours before the final transformation, the nymphs are quiet or entirely quiescent. When ready to emerge, they may swim about for a time, or may clamber directly up on top of the rock they have been resting upon, until completely above the water line, and at the highest point available.

Leptophlebia—These nymphs are so slender that they readily slip through the meshes of a wire pillow cage, even as fine a mesh as sixteen bars to the inch failing to restrain most of them. Many were reared indoors, in glass dishes placed on the window-sill. For others, a lining made of coarse cloth was sewed into an ordinary pillow cage, as high up as the water line. For their final transformation from the nymphal stage, they float free at the surface of the water.

Blasturus—Seldom found in absolutely quiet water, but often near borders of ponds or lakes, usually among aquatic plants, where the wash of the water creates a slight stir. Often feign death when taken from the water. Most readily taken with a dipnet.

These nymphs are evidently omnivorous, for in addition to a diet of diatoms and algae they have often been observed feeding on the cast skins of nymphs, of their own or another species. On emerging from its skin, a nymph has often barely moved away before other nymphs are tugging at the cast-off coat. The head and usually the last three or four segments of cast skins are seldom eaten, though this does not hold true for all cases observed. When a nymph dies, its body is eagerly devoured by its fellow nymphs.

For the transformation to the subimago stage, these nymphs often cling to some trash or aquatic plant so that the head and prothorax are out of water. Others transform while floating free at the surface.

Ephemerella—Found in various habitats. See notes under the different species of this genus. May be taken by hand-picking, or by the use of the hand-screen. These nymphs also feed on dead nymphs of their own or other species. They cling so tenaciously to the dead body as often to be lifted out of the water when it is removed. As it is their habit to feign death for some seconds if disturbed, it is not always apparent at first glance which is the dead nymph and which the live one feeding upon it.

Nymphs of this genus swim about the dish frequently, as often with the ventral side uppermost as otherwise, apparently quite at ease in either position. When the stone to which they cling is lifted from the water, they sit perfectly still for some seconds, often blending so well in color with the background of the stone as to be difficult to locate. They swim by means of undulations of the body, meantime holding the legs stiff.

Many species transform into the subimago state while floating free at the surface. Others cling with the fore feet to aquatic plants or rubbish, the head and thorax out of water.

Oreianthus—A sluggish stiff-legged nymph, looking like a bit of trash when caught on the hand-screen. It does not move at first, and would be easily overlooked except for its size and its erected tail. Found only in swift and moderately deep water, under the largest stones. No specimens were caught except by the use of the hand-screen. Was not observed when transforming, but the last nymphal skins were found floating on the surface of the water in the cage.

Isonychia—Very active swimmers and leapers, mostly found under large rocks in swift water. Usually these are caught most readily by the use of the hand-screen. When in leaf drift or in shallow water when ready to transform, many may be taken by hand-picking. When ready to transform, they leave the deep rapid water for shallower parts of the stream near shore, where an active current flows over small stones. Here they rest among the small stones, or hide, sometimes half out of water, under larger flat stones. They may be caught, as mentioned previously, by trapping them in a small pocket or pool.

For the final transformation, they climb partially or entirely out of water, up on the bank or on the exposed surfaces of stones. Often the cast skins are found several layers deep on one stone.

Siphlonurus—Active nymphs, which leap like small minnows up and

out of the net and back into the water, if given an opportunity to do so. Found in ponds and along shores of lakes, in the same habitat as Blasturus. They, too, will eat the cast skins of other nymphs, as well as their dead bodies. For the final transformation they climb partly or wholly out of water, on emergent vegetation or on stones.

Siphloplecton—Very similar in habits and habitat to Siphlonurus. Often, like the former, found among aquatic plants or trash near the shore, where there is a slight but constant movement of the water.

Baetis—These nymphs are difficult to rear indoors except in cages in running water, as they die in a few hours if placed in quiet water. The smaller species readily escape through the meshes of a wire cage. Some were reared in cages lined as for Leptophlebia. For transformation they float free at the surface of the water.

Callibaetis—Nymphs of this genus were the only ones found in absolutely stagnant water. Over a hundred were taken from a very small temporary pool, where they had congregated in holes made by the hoofs of a horse, in an inch or two of absolutely quiet water, exposed to the full glare of the sun. Strangely, not one of these completed its life cycle when taken indoors and placed in clean water, seemingly a much more favorable situation.

They fed upon the dead bodies of nymphs of their own species, and upon the bodies of dead tree-frog tadpoles which were numerous in the same small pool. Since the dead bodies were removed soon after taking the nymphs indoors, this would not seem to be the cause of their failure to transform.

Neocloeon—In behavior, very like Callibaetis and some species of Baetis. Usually rests on bottom of the stream, either on or partly under the shadow of leaves or trash. Ocelli ivory-white, appearing luminescent. Transform while floating at the surface of the water. Found only in small spring-fed streams with gentle current.

Caenis and Eurycaenis—In mud and silt, near the shore, in small ponds and streams.

3. Subfamily HEPTAGENINAE

Heptagenia—Some species are found in relatively quiet water, but the majority inhabit rapidly-flowing streams. May be taken either by hand-picking or with the hand-screen. They are rather quick to slip off from the rock as it is lifted from the water, and regain their native stream. Nymphs of this genus are hardy, and except in hot weather may be reared readily in open dishes indoors. When ready to transform they float at the surface of the water.

Ecdyonurus—Some species quite closely resemble Heptagenia in their habits. Others, both in general shape of body and in actions, are more closely allied to Rhithrogena. They float at the surface when ready to transform.

Epeorus—These nymphs inhabit the swiftest-flowing waters, although they are often found in less rapid currents. They are as prone to rest on the upper as on the under surface of a rock over which a torrent of water is pouring. There they seem to watch every movement of one who would capture them, and at the shadow of an approaching hand dart quickly to the sheltered under surface of the rock. A few will fall back into the water when a stone is lifted free, but many remain perfectl y quiet. Some will quickly sidle to the under side of the rock, as quickly sidling the other way if the rock is reversed. The majority sit perfectly still until the fingers of the collector approach, then try to escape. They tend to sit in rows near the edge of the rock, heads usually toward the outside, and many will be overlooked at the first glance. Large flat rocks are preferred by them. None of these nymphs were successfully reared indoors. Nymph skins were found floating on the surface of the water in the cages, or with the forefeet and head out of water as the nymph had clung to the wire of the cage.

Rhithrogena—While apparently better equipped than Epeorus, by reason of the complete disc formed by the gills, to cling to rocks in very rapid water, these nymphs were seldom found in the swiftest parts of the current. Unlike Epeorus, they are more frequently found on small, irregularly shaped smooth stones, and in water several inches only in depth, in a fair but not very rapid current. When the rock is lifted from the water, they may quickly sidle to the under side, or slip into a convenient crevice. Others sit perfectly still until the observer tries to pick them off. Difficulty is experienced in this procedure, as the nymphs adhere so tightly to the rocks as to be removed by the fingers only at the risk of injuring the delicate creatures. A grass blade slipped under the head of the nymph and used as a lever to pry it loose from the rock has been found effective. It may then be lifted up and put into the rearing cage without being touched by the fingers.

Even with such precautions, the death rate among collected nymphs was very high. Dozens died to one that transformed. Many escaped through the meshes of the net. Subimagoes often fell back into the water and drowned themselves almost as soon as they emerged. All told, while many nymphs were seen and collected, they were at no time nor place really numerous, and less success was met with in rearing them then with any one of the other genera concerned except Callibaetis.

Notes on the subimago stage

In the case of several species of mayflies, very accurate account was kept of the exact number of hours spent in the subimago stage. Occasionally the length of this period was known approximately but not exactly. A brief tabulation of the species observed, the number of individuals of each sex in which the length of the subimago stage was recorded, and the number of hours spent in this stage, is presented. Hours given are the shortest and the longest number recorded.

SPECIES	INDIVIDUALS	NUMBER OF HOURS
Hexagenia carolina	3 females	22½–27
	2 males	22–24
Siphlonurus quebecensis	6 (no sex listed)	47½–48
	8 males	47–53
Siphlonurus mirus	1 female	36–40
	1 male	51½–53½
Siphloplecton signatum	3 females	47½–61
	1 male	44
Blasturus gracilis	2 females	24–41½
	3 males	46½–51½
Blasturus grandis	4 females	18½–29
	2 males	19½–25½
Blasturus austrinus	7 females	20–24½
	7 males	19½–22½
Ephemerella cornuta	1 male	23½–26
Ephemerella inconstans	3 females	40½–51½
	4 males	26–49½
Baetisca carolina	13 females	21–52
	4 males	22–23½
Neocloeon alamance	1 male	7
Isonychia albomanicata	1 female	22–26
Isonychia aurea	1 female	31

IV. SYSTEMATIC

Genera of mayflies found in North Carolina

Twenty-seven genera are represented among my material. The following key to the imagoes of these twenty-seven genera is adapted partly from Prof. Needham's key, published in Ward and Whipple's *Fresh Water Biology* (1918–19, pp. 918–921), and partly from Dr. Ulmer's key, published first in Stettiner Entomologische Zeitung, 1920. The key to the nymphs is adapted from the *Guide to the Study of Freshwater Biology*, by Needham and Needham, 1927, pp. 10–14.

The three subfamilies recognized by Prof. Needham are accepted, rather than the suborders and families recognized by Dr. Ulmer. Miss Morgan's interpretation of wing venation is followed, although it is believed that a thorough revision of mayfly wing venation is much to be desired. In the key to the imagoes, venational characters are of the forewing, unless otherwise specified.

The genus Oreianthus seems to fall very close to the subfamily Ephemerinae, and is rather difficult to separate from this subfamily on good characters. But the nymph has the characters of the subfamily Baetinae, where it falls close to Caenis and Eurycaenis. Hence the genus is considered as belonging in the subfamily Baetinae, although this fact is not evident in the key to the imagoes.

Species of the four genera Heptagenia, Ecdyonurus, Epeorus and Rhithrogena (subfamily Heptageninae) are not dealt with in this paper, as the group is so large as to make a separate account desirable. Such a separate treatment of this subfamily will be prepared at a later date, to supplement the present account of the other two subfamilies of the order. These four genera are, however, included in the keys and in the general discussions of habits and habitat, as herewith presented.

KEY TO GENERA OF N. C. MAYFLIES—IMAGOES

1. Cubital and first anal veins strongly divergent at base. Venation never greatly reduced.....2
   Cubital and first anal veins parallel at base (in a few forms with reduced and scanty venation, appearing a little divergent).....5
2. In hind wing, cubital vein forked at somewhat more than halfway to margin; costal angulation of hind wing prominent; median carina on prosternum; fore coxae separated by space equal to length of prosternum....*Oreianthus*
   In hind wing, cubital vein either not forked, or forked near the base of the wing, where a prominent costal angulation is present; no such median carina on prosternum; fore coxae very close together, separated by space less than half the length of the prosternum....Subfamily EPHEMERINAE, 3

3. The third anal vein not forked, but attached to the hind margin of the wing by a series of cross veins; forceps of male 4-jointed.....4
The third anal vein ends in a single fork, and is not attached to the hind margin of the wing, though a few isolated intercalated veinlets lie between; male forceps 3-jointed.....*Potamanthus*
4. Two long tails in male and female; in foreleg of male, tarsus about 1⅔ to 1¾ as long as femur; in female, pronotum longer than broad.....*Hexagenia*
Three long tails in male and female; in foreleg of male, tarsus about four times as long as femur; pronotum of female shorter than broad.....*Ephemera*
5. Intercalary veins between the first and second anal veins unattached basally and in two pairs, of which the pair nearer the hind angle is the longer; venation never greatly reduced; eyes of male simple and remote; hind tarsi with five freely movable segments.....Subfamily REPTAGENINAE, 6
Intercalary veins between first and second anal veins never as above; venation various, sometimes greatly reduced; eyes of male enlarged, often approximated on the dorsal side and divided into superior and lateral portions with corneal facets of different sizes; hind tarsi usually with but four freely movable segments.....Subfamily BAETINAE, 9
6. First tarsal segment of the hind leg shorter than the second.....*Heptagenia*
First tarsal segment of hind leg as long as or longer than the second.....7
7. In the fore tarsus of the male, the first segment is as long as or longer than the others; claws of fore leg of male similar, blunt; dissimilar on the other legs and in the female; first segment of fore tarsus of female about as long as the second.....*Epeorus*
In the fore tarsus of the male, the first segment is shorter than several of the following segments; claws of all legs dissimilar, in both sexes; first segment of fore tarsus of female shorter than the second.....8
8. First segment of fore tarsus in male shorter than the fifth; 10th sternite of male usually concave in the middle of the hind margin; in foreleg of female, fifth segment of tarsus about twice as long as first.....*Rhithrogena*
First segment of fore tarsus in male longer than the fifth; 10th sternite of male slightly convex in the middle of the hind margin; in foreleg of female, fifth segment of tarsus less than 1½ times as long as the first....*Ecdyonurus*
9. The three anal veins nearly parallel to the hind margin of the wing and to each other, ending in the outer margin; in the hind wing the branches of the radial vein are strongly unilateral on the anterior side.....*Baetisca*
Anal veins strongly divergent distally, usually both the second and the third ending in the inner margin; branches of the radial vein in the hind wing more symmetrical.....10
10. The posterior division of the median vein with a normal posterior fork; hind wings, when present, usually but little longer than broad and with a copious venation.....11
Posterior fork of the median vein apparently simple, M_4 being detached and appearing as an intercalary; hind wings when present at least twice as long as wide, and provided with but 1–3 longitudinal veins.....22
11. The intercalaries between the first and second anal veins variable, but usually more or less independent, and not directly dependent upon the first anal; three well-developed tails (except in most species of Blasturus, in our fauna).....12

The intercalaries between the first and second anal veins represented by a series of veinlets, often sinuous or forking, extending directly from the first anal to the wing margin; costal angulation of hind wing close to the base; but two well-developed tails, the median one being rudimentary or wanting; hind tarsi five-segmented, the basal joint more or less united with the tibia.....19

12. Hind wings present.....13
Hing wings absent.....17

13. Bisector of the cubital fork independent; between it and Cu_2 no intercalaries; vein Cu_2 in the hind wing rarely preserved; tails generally much longer than the body; penultimate segment of the male forceps shorter than the antepenultimate.....14
Bisector of the cubital fork tending to be attached to the posterior branch of Cu_2; between this bisector and Cu_2 are generally some short intercalaries; tails about as long as body; penultimate segment of the male forceps longer than the antepenultimate.....*Ephemerella*

14. Hind wing obtuse oval, costal region narrow, long; costal margin weak and irregularly arched, interrupted in the middle by a shallow indentation; no costal angulation.....15
Hind wing with an angular lobe projecting forward from the middle of the costal margin; costal region broad and usually greatly shortened, rarely long; few cross veins in hind wing.....16

15. Median tail as long as or longer than the lateral ones; third anal vein of hind wing wanting.....*Leptophlebia*
Median tail much shorter than the lateral ones (except in *B. gracilis*); third anal vein of hind wing present, and often followed by one or two additional intercalaries.....*Blasturus*

16. Vein Sc of hind wing reaching almost to the apex, therefore long; basal segment of genital appendages hardly as long as the two terminal segments together.....*Habrophlebia*
Vein Sc of hind wing ending right behind the costal projection, being therefore greatly shortened; basal segment of genital appendages much longer than the two terminal segments together.....*Habrophlebiodes*

17. Vein Cu_2 and cubital bisector of forewing as long as Cu_1, both therefore running up to the base; cross veins of wings arranged singly; no intercalary region with more than one cross vein, only radial region with 2 or at most 3 cross veins; genital appendages 1-segmented.....18
Vein Cu_2 and cubital bisector much shorter than Cu_1 in forewing, not extending up to the base; cross veins of wings not arranged singly, but much more numerous, almost all intercalary spaces with several to many cross veins; genital appendages two to three segmented.....*Tricorythus*

18. Prosternum very narrow, two to three times longer than broad, the fore coxae therefore closely approximated; second antennal segment not lengthened *Caenis*
Prosternum very broad, twice as broad as long, the fore coxae therefore widely separated; second antennal segment three times as long as the first *Eurycaenis*

19. Hind tarsus shorter than or at most as long as tibia; fore tarsus of male varying in length.....20

Hind tarsus longer than tibia; fore tarsus of male at least twice as long as tibia.....21
20. Claws of all tarsi dissimilar.....*Ameletus*
Claws of fore tarsi similar, blunt; claws of second and third tarsi similar, pointed.....*Isonychia*
21. Claws of all tarsi similar, narrow, hooked.....*Siphlonurus*
Claws of all tarsi dissimilar.....*Siphloplecton*
22. Hind wings absent.....23
Hind wings present.....24
23. Short free intercalaries arranged singly on outer margin of wing....*Neocloeon*
Intercalary veins arranged in pairs.....*Pseudocloeon*
24. Fore wings with numerous costal cross veins before the bulla; hind wings with a moderate number of cross veins, at least in the costal region..*Callibaetis*
Fore wing without costal cross veins before the bulla; hind wings without cross veins, or with but 1–3 of them.....25
25. Marginal intercalary veinlets single.....*Centroptilum*
Marginal intercalary veinlets in pairs.....26
26. Hind wings oblong, usually with a short costal angulation; with 2 or at the most 3 longitudinal veins.....*Baetis*
Hind wings very small and narrow, without costal angulation; only 2 simple longitudinal veins.....*Acentrella*

KEY TO GENERA OF N. C. MAYFLIES—NYMPHS

1. Mandible with a tusk projecting foreward and visible from above the head Subfamily EPHEMERINAE, 2
Mandible with no tusk that is visible from above.....4
2. Fore tibia longer than hind ones.....*Potamanthus*
Fore tibia shorter than hind ones.....3
3. Elevated frontal process on head rounded.....*Hexagenia*
Elevated frontal process on head bifid.....*Ephemera*
4. Head strongly depressed; eyes dorsal.....Subfamily HEPTAGENINAE, 5
Head not strongly depressed; eyes lateral.....Subfamily BAETINAE, 8
5. Tails two.....*Epeorus*
Tails three.....6
6. Gills of last pair, tapered filaments.....*Heptagenia*
Gills of last pair, flat plates.....7
7. Gills of first and last pairs directed laterally.....*Ecdyonurus*
Gills of first and last pairs convergent ventrally.....*Rhithrogena*
8. Gills completely concealed beneath an enormously enlarged thoracic shield *Baetisca*
Gills exposed; thoracic dorsum normal.....9
9. Outer tails fringed on both sides.....10
Outer tails fringed only on the inner side.....18
10. Gills on abdominal segments 1–7, double.....11
Gills absent from one or more of segments 1–7; one pair usually more or less elytroid, covering those behind it.....14
11. Gills filamentous.....12
Gills lamelliform, at least on the middle segments.....*Blasturus*
12. Each a pair of simple filaments.....13
Each a pair of clusters of slender filaments.....*Habrophlebia*

13. Labrum rather deeply cleft on the front margin; second and third segments of labial palp about equal in length, the latter conical distally *Habrophlebiodes*

Labrum very little indented on the front margin; third segment of labial palp considerably longer than the second, (often three times as long) *Leptophlebia*

14. Gills present on the seventh abdominal segment, often elytroid on the third or fourth segment; usually a pair of tubercles on the apical margin of each abdominal segment beside the mid-dorsal line ..... *Ephemerella*

Gills absent from the seventh abdominal segment; elytroid on the second segment; no such paired dorsal tubercles 15

15. Elytroid gill quadrangular 16

Elytroid gill triangular ..... *Tricorythus*

16. Elytroid gills usually grown together along median line; a median dorsal keel on abdomen, with or without one median dorsal spine on segments 1–3 and 6–9 ..... *Oreianthus*

Elytroid gills not grown together along median line; no median dorsal keel nor spines 17

17. Three prominent ocellar tubercles on head ..... *Eurycaenis*

No such ocellar tubercles ..... *Caenis*

18. Posterolateral angles of the hinder abdominal segments prolonged into thin, flat, sharp lateral spines 19

Posterolateral angles of the hinder abdominal segments hardly more than acute—not prolonged into thin lateral spines 22

19. Fore legs conspicuously fringed with long hairs; gill tufts present upon the bases of maxillae and front coxae ..... *Isonychia*

Fore legs without conspicuous fringes; no maxillary or coxal gills 20

20. Fore claw short, broad and bifid at tip; other claws pointed, about twice the length of the fore claw ..... *Siphloplecton*

All claws pointed, none bifid at tip 21

21. Gill lamellae all single ..... *Ameletus*

Gill lamellae double on the basal abdominal segments ..... *Siphlonurus*

22. Gill lamellae double, at least on some of the basal abdominal segments *Callibaetis*

Gill lamellae single 23

23. Tails two 24

Tails three (in all known eastern forms) 25

24. Second pair of wing buds present ..... *Acentrella*

Second pair of wing buds absent ..... *Pseudocloeon*

25. Middle tail as long as outer ones; distal joint of labial palp much dilated at tip, its summit truncate 26

Middle tail shorter than outer ones; distal joint of labial palp not noticeably dilated at tip, its summit rounded or conical ..... *Baetis*

26. Gills symmetrical; tracheae of gill lamellae with normal pinnate branching *Centroptilum*

Gills asymmetrical, the inner margin extended into a lobe-like process; tracheae of gill lamellae pinnately branched, but all branches unilateral on the inner side ..... *Neocloeon*

Subfamily EPHEMERINAE

This subfamily is represented in my North Carolina material by three genera only; Hexagenia, Ephemera and Potamanthus.

GENUS HEXAGENIA Walsh 1863

Three new species of this genus were taken, one from each of the three geographic divisions of the state. Since descriptions of these species appeared in the September 1931 Annals of the American Entomological Society, along with four other new species of this genus, a brief summary only of each is given here.

Hexagenia elegans Traver

From the coastal plain region. Imagoes captured by Miss L. E. Brett from the Chowan River near Winton, in Hertford Co., N. C., during the second week of August, 1930.

This is a very small and dainty species, the males measuring 12–17 mm., the females 14–19 mm. The hind wings of the male are bordered with purplish brown; both wings have prominent purplish black spots. The abdomen of the male is marked prominently with purplish red. Genitalia very slender, of the *carolina* type. Body of female creamy white, the abdomen marked dorsally with dark grey.

Hexagenia carolina Traver

From the piedmont area, and a rather similar species from the Appalachian region at Franklin. In the piedmont, taken at Hamburg Lake, near Greensboro, in June 1930. Nymph skins were collected from the surface of the water, and nymphs which appear to be similar were later found in the South Toe River near Micaville, in the mountain region of the state.

This is a large species, predominantly yellowish white, the male marked with greyed rose to lavender. There is no dark outer border on the hind wing, and no prominent dark spots in either wing. Genitalia of the *carolina* type. The head of the female is sulphur yellow, also the metanotum. Abdomen marked much as in male, with median brownish grey stripe and lateral extensions of the same. Sternites 8–10 sulphur yellow. Males measure 20–24 mm., females 25–35 mm.

Hexagenia rosacea Traver

A single male, taken at Penrose in the mountains, probably from the French Broad River. Superficially quite similar to *H. carolina*, but differs from that species by the greater amount of color on the anterior abdominal segments, the shorter second tarsal joint, the larger compound eye, and by the appearance of the genitalia. Whitish, marked prominently with deep rose red. Genitalia of the *carolina* type. Size 20 mm.

Hexagenia sp?

Besides the three species above mentioned, nymphs, of a third and apparently undescribed species were taken from the Tuckaseegee River by Dr. J. S. Gutsell. Since only two immature subimagoes were among this material, it was not considered advisable to describe it as a new species, until more material becomes available. The nymph of this species is described as Nymph No. 6, in the before-mentioned paper on the genus Hexagenia. In this paper, likewise, are presented keys to the imagoes and nymphs of several species of the genus Hexagenia.

GENUS EPHEMERA Linn. 1746; restricted, Leach 1815

Ephemera blanda, n. sp.

MEASUREMENTS

	BODY	TAILS	FOREWING	FORELEG
Female nymph (4 specimens)	18–20	4½–7		
Male imago (2 specimens)	13–14	25–27	12–12½	12½–13
Female imago (2 specimens)	16–17	19	16–17	6–6½

Nymph brown dorsally, cream colored ventrally. Marked prominently with purplish-black lines. Gills purple. Wings of imago *lacking the usual pattern of dark blotches*; the normal location of these blotches, as in *E. varia*, represented by very small clouded areas only. Abdomen marked with blackish longitudinal pencillings.

Nymph

Head—Dark red-brown. A light cream-colored area laterad of each lateral ocellus. Epicranial suture narrowly white. Prongs forming each side of median frontal process blackish brown. Notch in frontal process straight on each side, rounded in center; see Pl. 12, Fig. 22.

Antennal sclerite, basal joint and distal half of second joint of antenna dark brown. Remainder of antenna light yellowish brown. Mouthparts as in Figs. 1 and 24.

Thorax—Dark red-brown dorsally, median line narrowly white. Cream colored ventrally. Anterior and posterior margins of pronotum narrowly black. A wide curving black band on each side of median line, not reaching the anterior margin. Mesonotum cream-white at anterior lateral angles, above wing-roots, a narrow band on each side of median line, and on mesonotal spine. Wing-cases very dark brown except for cream colored inner margin. A few small black blotches due to markings of enclosed wings.

Legs—Tibia and tarsus of foreleg dark brown, femur cream colored. Black spot at distal ends of femur and tibia. Other legs cream colored, margined narrowly with orange. Hairs tawny. Claw of third leg shown on Pl. 12, Fig. 33.

Abdomen—Yellowish to orange brown dorsally, tergites 7–10 darker. Tergites 2–6 with a pair of curving purplish-black marks on each side of median line, also a shorter mark at center of tergite nearer the pleural fold on each side. Tergites 7 and 8 similarly marked, with the addition of another narrower dark line nearer the median line on each side, in the anterior half of the tergite only. On 9, the two central narrow marks as in 7 and 8, but the wider outer marks are joined to form one bar on each side. Tergite 10 dark brown, no black markings. Ventrally cream colored, the last three or four sternites sometimes flushed with pale yellow. Sternites 3–9 with a black mark on each side of the median line. On 3, this is a mere dot, on 6–9 a narrow line. Pleural folds cream colored on some specimens, amber on others.

Gills—Central portion and fringes dark purplish-grey. Rudimentary first pair of same color.

Tails—Light brown, joinings purplish. In distal half, several joinings will be light brown, then follow a group of three or more that are purplish, then another group of light brown. Fringed with purplish grey hairs.

Male imago

Head—Yellowish brown, darker on occiput and median portion of vertex. Compound eyes slate-grey, upper portion lighter than lower. Ocelli pearl-grey, ringed widely with black at base. Basal joints of antenna cream colored, black distally. Antennal filament grey.

Thorax—Pronotum yellow in median area, except on anterior border.

Margined and bordered with cream. A brown area lies within the cream margin. A black longitudinal stripe is present on each side, between the yellow median portion and the outer brown area. Mesonotum brown, sides in anterior portion margined with cream, the whole bordered with darker brown. Median line narrowly pale. Pleura cream colored with brown markings. Ventrally cream-yellow, except for dusky posterior portion of prosternum, and brown antero-lateral portions of mesosternum.

Legs—Trochanter and femur of foreleg, and distal half of tibia, yellowish brown. Basal half of tibia cream-yellow. Tarsus grey-brown, darker basally. Distal end of femur and both ends of tibia widely black. Joinings of tarsus narrowly blackish grey. Other legs cream-white, claws greyish.

Wings—No large dark blotches. Costal margin of forewing tinged with purplish brown. Cross veins in this area narrowly bordered with dark brown. Other cross veins of forewing, in areas which are centers of large blotches in wings of *E. varia*, bordered more widely with purplish brown. Wing thus appears clear except for four small brown clouded areas near the central disc and a somewhat larger one nearer the base. Longitudinal veins of forewing, and main cross veins, brown. Veins of costal area of hind wing yellowish, all others silvery white. Outer margin faintly and narrowly yellow.

Abdomen—Cream-white, segments 8–10 washed with yellow. Posterior margins of tergites grey, widest on 4–7. Tergites 1 and 2 with irregularly rectangular purplish grey patches, one on each side, halfway between median line and pleural fold. Curving purplish black pencillings arranged longitudinally on remaining tergites in this fashion. One on each side of median line, wider near anterior margin; laterad of each of these a second narrower line, fainter in color on tergites 3–6. On tergites 6–9, a short bar on each side is interposed between the median line and the darker longitudinal bar. This is faint on 6, distinct and extending almost to the posterior margin on 7 and 8. On 9, it extends only to the center of the tergites. On 7 and 8 the three bars on each side tend to run together posteriorly. On 9, the two outer bars are united into one dark streak. Besides these longitudinal markings, tergites 3–6 have three other blackish spots on each side. Two black dashes are present on the pleural fold, one near each lateral angle, and a third somewhat rounded spot nearer the center of the tergite and inward from the pleural fold. Pleural fold on 7–9 bordered with black, and a narrower black mark at the anterior angle of the fold on tergite 2.

Ventrally, purplish-black longitudinal pencillings are present, one on each side of the median line, on sternites 2–8. On sternite 1, two small dots, one on each side of the median line at the center. Sternite 9 has the median line purplish black except at the anterior and posterior margins, likewise two bars in the posterior half, in the same relative position as the dark pencillings on the other sternites. In addition, round brown dots occur, one on each side of the anterior end of the median dark line.

Tails—Olive brown, joinings dark brown. In places, only alternate joinings are thus darker than the segments of the tails.

Genitalia—Forceps base brown, forceps limbs grey. Quite similar to *E. simulans*, but the second joint of the forceps relatively longer and less curved than in that species. Third joint likewise somewhat longer proportionately. See Pl. 12, Fig. 15.

Female imago

Head and dorsal aspect of thorax much lighter brown than in male. Mesonotum cream except the anterior portion and the lateral borders. Thoracic pleura entirely cream, sternites white.

Foreleg silvery white tinged with yellow, blackish markings as in male. Other legs silvery, claws faint grey-lavender. Costal border of forewing lacking the brown wash characteristic of the male; the stigmatic area opaque white. Cross veins margined as in male, but more faintly. Only four indistinct purplish spots in central disc of wing, none toward base.

Abdomen cream-white. Tergite 1 entirely white; tergite 2 as in male. Tergites 3–9 marked somewhat as in male, with a double row of blackish pencillings on each side of the median line, forming thus four almost continuous black longitudinal streaks. On 8 and 9 appear faint marks nearer the median line, one on each side in the anterior half of each tergite. Ventrally very similar to male.

Tails very light tan. Near the base the first four joinings are brown, followed by a wide purplish black joining. For a distance the brown and purplish black joinings alternate. Distally the latter predominate.

Holotype—Male imago—French Broad River at Penrose, N. C., July 19, 1930. No. 1082.1 in Cornell University collection.
Allotype—Female imago—Cullasaja River south of Franklin, N. C., July 3, 1929. No. 1082.2 in C. U. collection.

Paratypes—Female subimago—Reared from nymph taken at South Toe River, near Micaville, N. C., July 6, 1930.
Male subimago, male imago and female imago—North Fork of Swannanoa River near Swannanoa, N. C., June 30, 1930. No. 1082.3–5 in C. U. collection.

Distribution—Rather general throughout the Appalachian region. Nymphs of this species were found burrowing in soft mud and ooze close to the banks of several different streams. On July 1 and 5, 1930, several were collected from the Rocky Broad River at Lecky Gap, not far from the town of Black Mt. Others taken were as follows. Davidson River, July 18, 1930; South Toe River near Micaville, July 6, 1930; North Fork of the Swannanoa River near Swannanoa, July 1, 1930; and immature nymphs at Little River near the town of Cedar Mt., July 12, 1930. Prof. Needham collected nearly mature nymphs, slightly larger than any from the above localities, at Horse Pasture River, on April 8, 1929. While these nymphs appear similar, there is a possibility that they are not *E. blanda*.

Adults of the new species *E. blanda* were usually taken only in the evenings at the lights of the automobile, when it was parked near the banks of a stream. Most of these were subimagoes, which were kept until they attained the imago stage. Dates and localities are as follows. Cullasaja River south of Franklin, July 3, 1929 (female taken while ovipositing); North Fork of Swannanoa River, June 30, 1930; South Toe River near Micaville, July 6, 1930; Toxaway River at Lake Toxaway, July 16, 1930; and at Penrose on the French Broad River, July 19, 1930.

Only one specimen was reared, a female subimago from a nymph taken at the South Toe River. This reared individual establishes the correct connection between nymphs and adults. It should be noted that the nymph slough does not show the black pencillings. This fact was observed also in the case of several nymphs which died just before completing their transformation to the subimago stage.

Considering the localities from which the nymphs and adults were taken,—rather small streams, well shaded by thick growths of trees on either bank, the water usually but a few feet in depth except for an occasional deeper hole,—it appears that *E. blanda* is rather similar in its habits to the species *E. guttulata*, an account of which is given by Dr. Kennedy. Its habitat is thus quite different from *E. simulans*, which is more commonly found in lakes or larger rivers.

GENUS POTAMANTHUS Pictet 1843–5; restricted, Eaton 1871

A few immature nymphs of this genus were taken in sandy riffles partly beneath or in the lee of large flat stones in the current of Laurel River, not far from Hot Springs, on June 29, 1930. When the sand was scooped up and held in the hand or placed on the tops of flat rocks above water level, the nymphs soon began to scramble out, and were thus easily located. Only three were found in the course of an hour's collecting. The water was quite shallow and warm where they were found.

As the nymphs were immature, they were placed at once in vials of alcohol. No other nymphs of this genus were found, and as none were reared, the species cannot at present be determined. A brief account of the characters of these nymphs is given, however, as they seem to differ from those of the species figured by Prof. Needham in his paper on Burrowing Mayflies.

Potamanthus sp? No. 1 (Immature nymphs)

Length of body of largest nymph, 9½ mm.; tails 6 mm. General color of body light straw yellow marked dorsally with chestnut brown. Irregular zigzag brown markings on head and dorsum of thorax. Mouthparts, as shown on Pl. 7, Figs. 22, 23 and 25. Legs barred with brown. See Pl. 7, Fig. 21. Dorsal pattern of abdomen varying somewhat on the different tergites, but rather typical on tergite 4, as shown on Pl. 7, Fig. 24. Gills cream colored, marked along main trachea with wide greyish lavender band. Fringes of same color. Tails cream colored, fringed with grey hairs. Ventrally without conspicuous markings of any sort.

A female subimago of the genus Potamanthus was taken at the lights of the automobile on June 30, 1930, from the North Fork of the Swannanoa River. On July 19, 1930, another female subimago was captured in similar fashion from the French Broad River at Penrose. The former died as a subimago, the latter successfully transformed to the imago stage. These females seem to be of the same species.

As yet, the females of the genus Potamanthus have not been sufficiently studied to make their identification positive, when no males of the same species are at hand. Of the five species recognized by Mr. Argo, and briefly discussed in his paper, none seem to correspond to the females from North Carolina. The infuscated cross veins of the fore wings of the N. C. species definitely prevent its inclusion in the species

P. rufous, P. diaphanus, or *P. myops.* The wing expanse—each fore wing measuring 13–14 mm.,—prevents its being placed with *P. verticis* or *P. flaveola* (these species, according to Dr. McDunnough, are synonymous). Dr. Banks, in his account of *P. medius,* makes no mention of the veins of the wings, but does speak of "a broad median reddish stripe on prothorax and vertex of head, and less distinctly on mesothorax." As no such reddish stripe is present in the North Carolina form, it cannot be *P. medius.* The type specimen of *P. inequalis* cannot be located; Mr. Argo has considered it to be synonymous with *P. diaphanus.*

As all the previously described species of this genus would seem thus to be ruled out, the North Carolina form is probably a new species. It is briefly described here, but for lack of adequate material and the absence of males of the same species, is designated by number only.

Potamanthus sp? No. 2

MEASUREMENTS

	BODY	TAILS	FOREWING	FORELEG
Female subimago	15	16	14	6½
Female imago	12	18	13	6½

Female imago

Body pale yellowish white.

Head and median area of mesonotum ivory white. Compound eyes black, distance between these equal to about 2½ eye diameters. Ocelli light pearl-grey, ringed basally with purplish-black.

Thorax—Pleura very faintly flesh-tinted, main sclerites very narrowly bordered with black. Posterior margin and spine of mesonotum likewise narrowly black-bordered.

Legs—Femur of foreleg faintly yellowish. Basal joints of tarsus washed with pale grey, the joinings narrowly brown. Other legs silvery white, tarsal joinings similar but even narrower.

Wings—Cross veins in central disc of both fore and hind wings, and more faintly those toward apex of forewing, margined narrowly with greyed lavender. Stigmatic area of forewing slightly opaque, remainder of both wings transparent. Longitudinal veins and unmargined cross veins silvery.

Abdomen—Eggs impart an orange to flesh-colored cast to the abdomen. Segments 9 and 10 washed with very pale yellow, more opaque than anterior segments. No distinct markings of any sort.

Tails—Silvery white, no different color at joinings.

Female subimago

Differs from the above only in these features. Entire body more definitely washed with pale yellow. Fore legs light straw yellow, claws reddish brown; joinings of tarsus reddish brown. Other legs paler yellow. Tails pale yellowish, very slightly darker at joinings. Fringed with yellow hairs.

Subfamily BAETINAE

My collections from North Carolina include two new genera in this subfamily, namely Oreianthus and Neocloeon. Other genera represented are; Baetisca, Leptophlebia, Habrophlebia, Habrophlebiodes, Blasturus, Ephemerella, Caenis, Eurycaenis, Tricorythus, Siphlonurus, Siphloplecton, Isonychia, Ameletus, Baetis, Pseudocloeon, Centroptilum, Acentrella and Callibaetis.

GENUS OREIANTHUS Traver 1931

An account of this genus, and of the single species, *Oreianthus purpureus*, at that time known in the genus, appeared in the Canadian Entomologist **63,** in May 1931. The genus is particularly interesting in that the nymph is very close to Caenis, and is apparently the same genus, though a different species, as that described by Joly from the Garonne River, France, in 1871; while the imago falls, by reason of its wing venation, close to the subfamily Ephemerinae. The general appearance of the imago, other than the venation, is as close to certain members of the subfamily Baetinae as to the Ephemerinae, and I think it is more closely allied to the former than to the latter group.

On Pl. 5 the distinctive features of this genus, both nymph and adult, are presented. It should also be mentioned that since the appearance of the account of the genus, another species of the genus, nymph only, has been sent to the Cornell University collection by Prof. P. W. Fattig, of Emory University, Ga. This nymph will be described in a later paper. *Oreianthus purpureus* is also represented among Prof. Fattig's material, and a new record for its occurrence in North Carolina is a specimen taken by Dr. J. S. Gutsell, of the Bureau of Fisheries at Beaufort, N. C., in the Tuckaseegee River, on Oct. 22, 1930. The female imago of *O. purpureus* measures 16 mm., male imago not known.

I should like also to call attention to the fact that through an error, a wrong type number was assigned to the species *O. purpureus*. The correct type number for this species is 1002, in the Cornell University collection.

GENUS NEOCLOEON Traver 1931

The description of this genus, and of the single species *Neocloeon alamance*, will appear in a forthcoming issue of the Journal of the N. Y. Entomological Society. On Pl. 6 are presented the main characteristics of this genus, both nymph and imago. It is close to Cloeon, Pseudocloeon, and the several other genera allied to these two. The nymph possesses three tails; the labial palp is dilated at the tip, as in Centroptilum; the gills are single, the inner margin prolonged into a lobe so that the shape of each gill is asymmetrical; the tracheae branch pinnately, but all branches are unilateral on the inner side. The imago lacks the second pair of wings; intercalaries of the fore wing are single; the genitalia are rather close to some species of Centroptilum. The male imago of *N. alamance* measures 5–6 mm.; the female, 5½–7 mm.

GENUS BAETISCA Walsh 1862

Baetisca carolina Traver

This species was described in the Journal of the N. Y. Entomological Society **39**, March, 1931. The nymph differs from that of *B. obesa* Say in the absence of dorsal spines on the mesonotal shield, and in the greater length of the maxillary palp. The dark areas of the wings of the subimago are more extensive than in *B. obesa*. Hind wing almost entirely, and fore wing basally, flushed with bright orange. Easily distinguished from *B. rubescens* Prov., in which the wings are flushed with reddish, by its much larger size. Male imago measures 8½–10 mm.; female imago, 8–10½ mm.

This species is represented in my collection only from the piedmont area, where it was taken in two different stations in the vicinity of Greensboro. Later, Dr. J. S. Gutsell obtained a nymph of this species from the Tuckaseegee River in the western part of the state.

GENUS LEPTOPHLEBIA Westwood 1840; restricted, Etn. 1881

Leptophlebia moerens McD.

Mature nymphs of this species were found in a small stream in the outskirts of Greensboro, on April 13, 1930. Many more were taken at the same stream three days later, several of these transforming the same day. The remainder transformed between this date and April 27. Examination of the genitalia of the male imagoes shows this species to be *L. moerens*.

Leptophlebia guttata McD.

Male imagoes of this species were picked out of a spider's web over a small tributary of one branch of the Pigeon River between Waynesville and Hazelwood, and others caught in their noonday 'dance' above the same stream, on July 18, 1929. A nymph taken from this stream two days later died without transforming. It has the long maxillary palp and other structural features of the species *L. guttata*, to which species the imago males also belong. The labial palp of this nymph is shown on Pl. 7, Fig. 14. The molar surfaces of the mandibles are unusually well developed; see Pl. 7, Fig. 20. Another nymph of this species was taken near Swannanoa on June 15, 1930.

Leptophlebia debilis (?) Wlk.

An immature nymph, taken in Big Alamance Creek on Oct. 19, 1929, is referred to this species, on the basis of its mottled abdominal tergites, the structure of the gills, the dark bands on the legs and the mouthparts. No imagoes of this species were secured.

Leptophlebia swannanoa, sp. nov.

Nymphs of this species were first found in considerable numbers in the North Fork of the Swannanoa River, near Black Mt., on June 14, 1929. They were not yet fully mature. In 1930, mature nymphs were taken from this stream on June 12, and again on June 14, and reared to the imago stage. Several of these transformed on June 15. The species proves to be a new one, allied to the "mollis-adoptiva" group. Gills of the nymph most resemble those of *L. adoptiva*, while the mouthparts are more like those of *L. mollis*, but with the canines of the mandibles much more highly developed. The genitalia of the male imago differs somewhat from *L. mollis*, but bear a general similarity to this species.

Nymphs of *L. swannanoa* were taken at a number of other streams in the Appalachian region during the summers of 1929 and 1930. These localities are as follows. The Ocona Lufty River near Cherokee, July 2, 1929; the Cullasaja River thirteen miles south of Franklin, July 3, 1929; a small tributary of the Pigeon River near Hazelwood, July 15, 1929; Davidson River in the Pisgah National Forest, near the town of Pisgah Forest, June 20, 1930; a tributary of the French Broad River at Selica, July 13, 1930; and a small tributary of the Davidson River, July 19, 1930. Imagoes were obtained only by rearing nymphs from the North Fork of the Swannanoa River.

It is interesting to note that *L. assimilis* Bks. was taken from the North Fork of the Swannanoa River in the month of May. However, Dr. Banks' statement that his species is "very close to *L. praepedita*" would seem to indicate that the new *L. swannanoa* cannot be synonymous with *L. assimilis* Bks.

MEASUREMENTS

	BODY	TAILS	FOREWING	FORELEG
Male nymph (9 specimens)	4½–5	2–2½		
Female nymph (11 specimens)	4½–5½	2–4		
Male subimago (1 specimen)	4½	4	5½	2
Male imago (1 specimen)	5	6½	5½	5
Female imago (2 specimens)	5	4	5½	1½–2½

Nymph distinguished readily by the great overdevelopment of the canine area of the mandibles. Gills with tracheoles. Male imago with abdominal segments 2–7 white, unmarked except for dark stigmatic dashes. Genitalia very similar to *L. mollis*.

Nymph

General color reddish brown.

Head—Light reddish brown. Middle ocellus much smaller than lateral ones. A large white spot laterad of each lateral ocellus, a small white spot anterior to median ocellus. Head square, the large mandibles with their greatly developed canines being very prominent. See Pl. 7, Figs. 2 and 12 for mouthparts. Four pectinate hairs below crown of maxilla. Median line of clypeus white. Antenna dark brown at base, remainder light brown. Maxillary palp barred with dark brown.

Thorax—Reddish brown, slightly darker than head. Median line of pronotum narrowly, and lateral margins widely whitish. Median line of mesonotum white, also three indistinct spots; one laterad and anterior of the mesonotal spine on each side, the third on the mesonotal spine. Pleura white between the sclerites. Very light brown ventrally.

Legs—Light brown barred rather indistinctly with darker brown. A wide bar on the distal half of the femur, a narrower band at proximal end of the tibia, and a darker wide band on the basal half of each tarsus. Claws with teeth along inner margin.

Abdomen—Dark reddish brown dorsally, light brown ventrally. Tergites darker near pleural fold on each side, and indistinctly mottled with grey-brown on each side of median line, which is faintly lighter.

A dark grey bar on each side of each sternite, near the pleural fold; on sternite 1, this forms rather a large spot. A rather short postero-lateral spine on 9, none on segment 8.

Gills—With tracheoles, branched about one-third from the base. See Pl. 7, Fig. 6a, for appearance of gill.

Tails light brown.

Male imago

Very similar to *L. mollis*. Distinguished from this species by the black stigmatic dashes on the abdomen and the lack of an opaque cloud in the stigmatic area of the forewing.

Head—Brown. Antennae light tan. Ocelli grey. Upper part of compound eye orange-brown; lower part bluish black.

Thorax—Dark reddish brown. Darker area at posterior border of pronotum, on each side of the median line, and at postero-lateral angles. Mesonotum bordered narrowly with darker brown. Center of mesonotum somewhat lighter brown.

Legs—Silvery white, except coxa, trochanter and femur of foreleg, which are slightly washed with yellow.

Wings—Transparent, slightly iridescent. All veins silvery white. No opaque area in stigmatic area of forewing, as in *L. mollis*.

Abdomen—Tergite 1 dark brown, with saddle-shaped yellow marking in anterior half, not reaching to pleural fold on each side. Sternite 1 yellowish brown except next to pleural folds, where it is dusky brown. Segments 2–6 translucent silvery white, with only a faint dark mark in the pleural fold at the stigmatic area. Segment 7 opaque, yellowish white; posterior margin of 7th tergite yellowish brown. Segments 8–10 dark reddish brown, darker along pleural folds.

Tails—Silvery white.

Genitalia—Of the "mollis-adoptiva" type, quite similar to *L. mollis*. See Pl. 7, Figs. 3 and 13, for side and ventral views.

Female imago

Head—Yellowish. Ocelli grey, ringed basally with black. Compound eyes black.

Thorax—Pronotum yellowish in anterior center, light greyish brown elsewhere. Darker oblique bar from postero-lateral angle forward and inward, reaching anterior margin on each side of the median line. Mesonotum light reddish brown except for a yellowish streak forward from the wing roots. Metanotum and pleurites somewhat darker red-

brown. Prosternum yellowish, with grey patch on each side from inner base of leg almost to median line. Center of anterior half of mesosternum yellowish; posterior half rather dark brown.

Wings as in male.

Legs entirely silvery white.

Abdomen—Reddish brown, somewhat lighter ventrally. Segments 8–10, and sternite 1, greyish brown. Pleural fold white. A dusky line parallel and adjacent to this white border on each tergite. Tergites 2–7 with indistinct lighter pattern; from anterior border on each side of median line a backward-directed mark reaching about to the center; median line itself lighter. An irregular lighter patch on each side, halfway from median line to pleural fold on the anterior border, extending backwards three-fourths of the tergite. Large yellowish patch on 9, occupying most of each side of the tergite from the anterior border. Smaller patch in same position from posterior border, the two light areas separated by a grey band. Sternites dusky on each side next to pleural fold, and a darker area in center of posterior margin of 7. See Pl. 7, Fig. 11, for shape of posterior margin of 9th sternite.

Tails as in male.

Male subimago

Darker than male imago, the abdomen greyish brown in portion which is silvery white in imago. Legs faintly yellowish, tarsi faintly greyed. Tails silver-grey, joinings faintly and narrowly brown.

Holotype— Male imago—Reared from nymph. North Fork of Swannanoa River, N. C., June 15, 1930. No. 1083.1 in Cornell University collection.

Allotype— Female imago—Same data. No. 1083.2 in C. U. collection.

Paratypes—Female imago and male subimago—Same data. No. 1083.3–4 in C. U. collection.

Leptophlebia sp? No. 1.

Several immature nymphs which are unlike any of the eastern species thus far described were taken near Swannanoa on June 15, 1930. Others, apparently similar, were collected from Pinedale, near Greensboro, on April 24, 1930. Dr. J. S. Gutsell took nymphs that appear to be the same from Scott's Creek on April 8, 1930. A brief description of one of the nymphs from Swannanoa follows.

Uniformly brown. Body 6 mm.; tails 3½ mm. additional.

Head—Small light spot anterior to median ocellus, a larger one between the lateral ocelli. Vertex marked with black. Maxilla as on Pl. 7, Fig. 10. Labium and maxillary palp similar to *L. mollis*. Three pectinate hairs below crown of maxilla, as contrasted with five in *L. mollis* and four in *L. adoptiva*. Mandibles show no unusual features.

Thorax—Pronotum margined posteriorly and laterally with white. Legs not banded, but femur slightly darker in its distal third. Claws with spines.

Abdomen—Gills with tracheoles. Branched about three-sevenths from the main trachea. Fifth gill as on Pl. 7, Fig. 6. Postero-lateral spines present on segments 8 and 9, longer on 9.

Tails—Pale, faintly brown at joinings.

OBSERVATIONS ON THE MANDIBLES OF LEPTOPHLEBIA

Certain species of the genus Leptophlebia exhibit unique developments of the canine area of the mandibles. A tendency toward an enlargement of this region is noticeable in *L. adoptiva* (see Pl. 7, Fig. 16). In *L. mollis* this tendency has been carried much further (see Fig. 17). In *L. swannanoa* it seems to have reached its height (see Fig. 12, same plate). At first glance it might seem that the tusked mandible of the western *L. packii* Needham was the ultimate expression of this tendency. But in this species, it is the outer canine only which has become enlarged and elongated, the inner canine and lacinia remaining unmodified. Since *L. packii* falls into the 'moerens-guttata' group, and the three species first mentioned are of the 'mollis-adoptiva' group, it seems probable that the modifications of the former are the result of an independent line of development.

GENUS HABROPHLEBIODES Ulmer 1920

Habrophlebiodes americana Bks.

In the piedmont area, this species was found at one station only,—the Cascades, on a small stream tributary to the Dan River, near Danbury, N. C. This is in the Sauratown Mts. Nymphs taken here on May 12, 1929, were successfully reared to imagoes, which transformed on May 24.

In the mountain area of the state, imagoes were taken from a spider's web over a tributary of Wayah Creek, near Franklin, on July 2, 1929. Near Penrose, on July 8, 1930, two imagoes were taken in flight over a small spring-fed stream.

The nymph of Habrophlebiodes is strikingly similar to that of a Leptophlebia. The structure of the gills is like that of a Leptophlebia of the 'adoptiva-mollis' group. Mouthparts are in the main of the Leptophlebia-Blasturus type. Certain slight differences may be noted. The labrum is more deeply cleft on the fore margin than in Leptophlebia. Large hairs or spines are present below the crown of the maxilla, pectinate and set in circular bases as in Leptophlebia and Blasturus. They differ slightly from most of those of the above genera in extending upward from the base and then turning sharply outward at right angles to their previous course. The labial palp resembles Habrophlebia more than Leptophlebia, the third joint being short and somewhat conical. The second and third joints together are about as long as the first. A row of teeth is present on the inner margin of each claw. Abdominal segments 8 and 9 bear postero-lateral spines, that on 9 being somewhat the longer. Tergites 7 to 9 are margined posteriorly with relatively long spines. Mrs. Morrison has described this species as *Leptophlebia betteni*, and figured the gills and mouthparts, in the Canadian Entomologist 61:139–146.

Although the nymph is thus so similar to Leptophlebia, the peculiar hind wing of the imago and the ovipositor of the female probably justify its position in a separate genus.

GENUS HABROPHLEBIA Etn. 1881

Along with Habrophlebiodes, a few nymphs of Habrophlebia were taken on May 12, 1929, at the Cascades, in the Sauratown Mts. near Danbury. One of these, a male, transformed to the subimaginal stage on May 14, but died before becoming an imago. Examination of the genitalia of this specimen shows that it differs considerably from *Habrophlebia vibrans* Needham, the only other species of this genus thus far described from eastern North America. A new species, *H. pusilla*, is therefore proposed for this North Carolina form. It is to be noted that the species described by Banks from near Black Mt., N. C., as *H. jocosa*, has been determined by McDunnough as identical with *H. vibrans*.

Habrophlebia pusilla, sp. nov.

Nymph

Described from nymph slough.

Length of body, 6 mm.; outer tails, 4¾ mm.; middle tail, 6 mm.

General color, light brown. No definite markings on body, other than a rather indistinct darker mid-ventral line on sternites 4–7.

Mouthparts—Very similar to those of *H. fusca*, as figured by Eaton in the *Revisional Monograph*, Pl. 36. Maxillary palp three-jointed, the distal joint shortest. Four to five large pectinate hairs below the crown of the maxilla, instead of seven as shown in *H. fusca*. Four spines or hairs at upper portion of inner margin, the second of these pectinate. Third joint of labial palp slightly shorter than the second. The second and third together are about equal to the first. Mandibles with three outer and three inner canines. Upper portion of lacinia comb-like. See Pl. 7, Figs. 4, 5, 7, 15 and 26.

Legs—Tibia and tarsus of each leg yellowish brown.; femur brown. No dark bands. Joinings narrowly darker. Tarsus of foreleg very slightly, and tarsi of other legs considerably, shorter than their respective tibiae. Claws with a row of teeth along inner margin, and near the distal and extending up on the side. Thirteen teeth on claw of foreleg.

Abdomen—Posterior margins of tergites set with short teeth or spines. Postero-lateral spines on tergites 8 and 9, that on 9 being somewhat the longer.

Gills—Each main trachea divides into two branches, each of which is soon subdivided into three parts, except gills of segments 1 and 7, in which one branch has but two subdivisions. First and fourth gills as in Pl. 7, Figs. 18 and 19.

Tails—Middle tail longer than outer ones. Light brown in color. Short hairs at each joining. In addition, in basal region each joining is margined with short blunt teeth or spines. Joints become progressively longer from base toward tip.

Male subimago

General color dark brownish. (Specimen was boiled for a few seconds in KOH, which changed its color to reddish brown. Markings were recorded before the specimen was boiled, but measurements taken afterwards.)

Length of body, 4 mm.; tails, 4 mm.; foreleg $2\frac{3}{4}$ mm.; forewing $4\frac{3}{4}$ mm.

Antennae brown at base, filament greyish.

Legs—Fore femur and distal end of tibia reddish brown; remainder of foreleg very light brown. Other legs greyish white, joinings very light brown.

Wings—See Pl. 3, Fig. 8, for hind wing. Wings light grey, no trace of amber near the base.

Abdomen—Large white patches near centers of tergites 3–6. On tergites 7 and 8, whitish lines parallel to and near the pleural folds. Sternites lighter brown than the tergites, without definite markings.

Tails—Greyish white.

Genitalia—Ventral view as in Pl. 7, Fig. 1. Side view, Fig. 9. Penes seemingly narrower than in *H. vibrans*. The appendages from these are much longer than in *H. vibrans*, reaching backward almost to the posterior margin of the 9th sternite. In ventral view these somewhat resemble the beaks of stork-like birds.

Holotype— Male subimago—Reared from nymph, May 14, 1929. Taken at the Cascades near Danbury, on a tributary of the Dan River. No. 1084.1 in C. U. collection.

GENUS BLASTURUS Eaton 1881

Provisional Key to Male Imagoes of Blasturus

1. Wings with definite brown cloud occupying the apical third of the forewing ..... *B. nebulosus*
   Fore wings without any such brown cloud in the apical third 2
2. Stigmatic area of forewing clouded with brown ..... *B. cupidus*
   Forewing without dark cloud in stigmatic area 3
3. Middle tail equal to outer tails in length. Abdominal segments 3–6 translucent white. Forceps limbs four-jointed, the third joint inflated distally. Small species, 5–7 mm. in length ..... *B. gracilis*
   Middle tail distinctly shorter and weaker than outer ones. Abdominal segments not as above. Forceps limbs three-jointed, rarely a partial fourth joint. Larger species, over 8 mm. in length 4
4. Large species, 11½ to 14 mm. in length. Penes of the "scarf" type, appendages reaching to the sinus between the limbs of the penes ..... *B. grandis*
   Smaller species, 9 to 11½ mm. in length. Penes of the "hooded" type, appendages not reaching to the sinus between the limbs of the penes ..... *B. austrinus*

Provisional Key to Blasturus Nymphs

1. Legs distinctly banded 2
   Legs not banded, or with indistinct bands 4
2. Medium to large species, 9–16 mm. in length. Six to seven large pectinate hairs just below the crown of the maxilla 3
   Smaller species, 7 to 9 mm. in length. Four large pectinate hairs just below crown of maxilla ..... *B. intermedius*
3. Medium-sized species, 10–12 mm. in length. Pronotum with black markings ..... *B. austrinus*
   Large species, 11½ to 16 mm. in length. Pronotum without black markings ..... *B. grandis*

4. First pair of gills with no lateral tracheal branches extending out from the two main divisions. No white marks on venter of abdomen. Small species, 5 to 7½ mm. in length.....5
   First pair of gills with lateral tracheal branches arising from each of the two main divisions. Venter of abdomen with four white marks near the median line.....6
5. Lower gill of third pair with the lateral lobes at the tip of the gill plate unequal. Spinous extension of the 8th abdominal segment slightly shorter than that of the 9th segment. Extension of median trachea of upper gill of third pair equal to or exceeding the gill plate in length.....*B.* sp. No. 2
   Lower gill of third pair with the lateral lobes at the tip of the gill plate approximately equal. Spinous extensions of 8th and 9th segments about equal in length. Extension of median trachea of upper gill of third pair shorter than the gill plate proper.....*B. gracilis*
6. Uppermost gill of third pair with the median extension of the main trachea as long as or longer than the gill plate proper. Lateral lobes at tip of lower gill of third pair unequal in length.....*B. nebulosus*
   Uppermost gill of third pair with the median extension of the main trachea shorter than the gill plate proper. Lateral lobes at tip of lower gill of third pair may be equal or unequal.....7
7. Lateral lobes at tip of lower gill of third pair unequal in length. 5 to 6 large pectinate hairs below the crown of the maxilla.....8
   Lateral lobes at tip of lower gill of third pair equal or approximately equal in length. 6 to 7 large pectinate hairs below crown of maxilla.....9
8. Fore claw with about 20 teeth on inner margin, 8 in upper row. Spinous extension of 8th abdominal segment approximately equal to that of the 9th *B. collinus*
   Fore claw with 16 to 17 teeth on inner margin, 5 in upper row. Spinous extension of 8th segment shorter than that of the 9th.....*B.* sp? No. 1
9. Spinous extensions of 8th and 9th abdominal segments about equal in length, both being long, slender and sharp-pointed. The 9th extends beyond the center of tergite 10. Fore claw with 8 teeth in upper row, 20 to 21 on inner margin.....*B. austrinus*
   Spinous extension of 8th segment shorter than that of the 9th. The latter rather blunt, not reaching to the center of tergite 10. Fore claw with 3 to 4 teeth in upper row, about 14 on inner margin.....*B. cupidus*

Distribution in the state

Many nymphs of this species were found, in all three of the major geographical divisions of the state. They were most numerous, however, in the piedmont area. From nymphs collected in the piedmont, many adults were reared, and three new species established for this section of the state. Two species of nymphs collected from tributaries of the Cape Fear River in the coastal plain region proved also to be new. Prof. Needham collected several subimagoes in Lenoir Co., in the coastal plain, two species of nymphs and a few adults from near High-

lands, in the Appalachian region. The three species from the piedmont, one from the mountains and one from coastal plain are named and described herewith, while the other two, for lack of adequate material, are designated by numbers only, and their chief characteristics indicated. Neither *B. cupidus* Say nor *B. nebulosus* Wlk. are represented in the collections from any part of the state. It is quite possible that the new *B. austrinus* is the species placed by Eaton under *B. cupidus* and designated as the 'variety from North Carolina.' The description of the western species *B. gravestellus* Etn. does not seem to apply to any of the North Carolina material.

Generic characters

Blasturus has been separated from Leptophlebia heretofore, as regards the imago stage, by the shorter middle tail of the former. In the new species *B. gracilis*, however, the middle tail *nearly or quite equals the lateral ones* in length. The gills of the nymph are of the Blasturus type. In the American species of Leptophlebia, the genitalia differ quite markedly from those of the known species of Blasturus. In the European *L. marginata* and *L. vespertina*, however, the genitalia are strikingly similar to some species of Blasturus, particularly of *B. gracilis*. A comparative and rather detailed study of the genera Blasturus and Leptophlebia would seem to be advisable. It is suggested that wing characters may prove useful in this respect, both as to venational differences and as to relative shape and size. Both fore and hind wings are wider in proportion to length than in Leptophlebia, the anal angle of the fore wing better developed. Cross veins in the costal cell before the bulla are very faint and indistinct, those in the apical third of this space are well developed and often anastomose. The hind wing of Blasturus has many more cross veins and marginal intercalaries than in Leptophlebia, the entire lower half of the wing being better developed.

Nymphs of Blasturus differ from those of Leptophlebia principally in the structure of the gills, the second to sixth pairs of which in Blasturus are lobed at the tips, while all seven pairs in Leptophlebia are more slender, simple and not lobed at the tips.

The claws of Blasturus have, in addition to the row of teeth along the inner margin, an extra upper row of teeth along one side, which teeth are not present in any Leptophlebia examined. Mouthparts of Leptophlebia vary greatly in the different species, while those of all the known species of Blasturus are so constant as to be of little or no use in classification.

Specific characters

Both as to nymphs and imagoes, the genus Blasturus is a difficult one to separate into its component species. Structural differences are minor and difficult to recognize until some time is spent in studying the group as a whole. Color differences exist, but are likewise minor and relative, and are an unsatisfactory basis for the separation of species. The combination of several minor and relative characters for each species is the best the writer is able to offer at the present time.

Nymphs

The number of teeth along the inner margin and in the upper row on the claws varies in different species, and within certain limits may be useful in distinguishing one from another. Gills of the first, third and seventh pairs have been studied, and those of the third pair figured, as a possible aid in identification. Large pectinate spines just below the upper margin of the galea-lacinia, each set in a circular base, have been found to vary in number in different species. While the other very numerous and much smaller spines on the crown of the maxilla are likewise pectinate, they are not set definitely in such prominent basal structures. Color patterns of head, thorax and abdomen, while more or less uniform throughout the genus, occasionally differ enough to mark off a definite species. Differences in color of mature nymphs as to the sexes must not be overlooked, as these may differ from the immature forms. At least two species may usually be separated by the distinct bars of darker color on the legs.

Imagoes

Imago males may be separated by differences in the genitalia, color differences of legs, body and tails, and sometimes by wing markings. Female imagoes show slight differences in the structure of the cleft plate which forms the apex of the ninth sternite. The male genitalia differ (1) in number and relative length of forceps joints; (2) in appearance of tip and outer margin of penes; and (3) in length and appearance of the elongated processes of the penes. As to length, in some species the tips of these processes, when fully extended as when mounted on a slide, do not reach as far as the sinus between the two parts of the penes. In other species, they reach to or beyond this sinus. One type of the penes processes forms a "hood" over the tips of the penes; a second type turns back and upward upon itself, giving the effect of a cape, or a scarf thrown over the shoulder. In one species, a definite indentation or sinus

is present on the outer margin of each portion of the penes; this is associated with the "scarf" type of processes, which are likewise as long as or longer than the sinus. In one species the forceps, which are usually three-jointed, are regularly four-jointed, and occasional specimens in other species show this same condition. Other variations will be noted in accounts of the species.

From the Appalachian region

Prof. J. G. Needham collected several Blasturus numphs and a few adults from Mirror Lake and Harbison's Pond, near Highlands, N. C. Two species are represented in this material, both of them apparently new. One is described here as *B. collinus* n. sp.; the other, represented by nymphs alone, is designated as *B.* sp? No. 1. No other representatives of this genus were taken from the Appalachian region of the state.

Blasturus collinus, sp. nov.

MEASUREMENTS

	BODY	OUTER TAILS	INNER TAILS	FORELEG	FORE-WING
Male nymph (5 specimens).....	8½–9½	8	11		
Female nymph (6 specimens).....	9–10½	9–10	10		
Male subimago.....	9½	Broken	Broken	5½	9
Female imago.....	10	17	Broken	Broken	9½

A medium-sized species, reddish brown in color in all stages.

Nymph

Head—Black between ocelli. Vertex mottled with black. Lighter brown laterad of lateral ocelli and forward from median ocellus, also on inner margin of compound eyes. Remainder of head dark brown. Five to six large pectinate hairs below the crown of the maxilla.

Thorax—Six white marks on pronotum. One on each side on anterior margin, halfway to lateral border. One on each side of median line, slightly back of anterior margin. A larger crescentic mark on each side near the lateral margin and somewhat parallel to it. Two indistinct small light areas above each wing root, on mesonotum.

Legs—Light red-brown, slightly darker at joinings. Not banded. Fore claw with about 20 teeth on inner margin, and 8 in the upper row.

Abdomen—Groundwork of tergites red-brown, with grey-brown W-shaped markings and lateral extensions from these. A yellowish mark

on each side of median line at anterior margin of each tergite. See Pl. 8, Fig. 18b. Ventrally, lighter red-brown. Each sternite with four white marks in the characteristic position, and on each side a dark bar parallel to and near the pleural fold. Female nymphs darker than males, both dorsally and ventrally. Spinous extensions of segments 8 and 9 approximately equal in length.

Gills—For gills of third pair, see Pl. 8, Fig. 9.

Tails—Reddish brown, slightly darker at joinings. Alternate joinings wider.

Male subimago

Body—Dark reddish brown, lighter ventrally.

Head—Blackish on vertex.

Thorax—Very dark brown dorsally. Pronotum narrowly bordered posteriorly with light brown. A longitudinal stripe of light brown on each side of mesonotum. Pleurites somewhat lighter than dorsal aspect. Ventrally dark red-brown.

Legs—Light red-brown, joinings slightly darker. Tarsi of second and and third pairs greyish brown.

Wings—The subimaginal cuticle was removed from one of the wings. No stigmatic cloud nor other dark area is present on the wing of the imago thus exposed. Veins in the stigmatic area show considerable anastomosis. Longitudinal veins, and cross veins on upper half of fore wing, light brown. All others faintly greyish to hyaline.

Abdomen—Very dark brown dorsally, somewhat lighter ventrally. Each tergite with a yellow mark from the anterior margin on each side of the median line, reaching to about the middle of the sclerite. Each is also narrowly bordered posteriorly with yellow. Ventrally, the ganglionic areas are yellowish brown. A dark spot on each side of median line at center of sternite 1. A narrow indistinct dark bar on each side of each sternite near pleural fold. Each sternite shows faint white markings near the median line, as in the nymph.

Tails—Dark red-brown, blackish at joinings. Alternate joinings wider.

Genitalia—See Pl. 8, Fig. 6.

Female imago

Light reddish brown, somewhat darker on dorsal and ventral aspects of thorax, and the markings of the abdominal tergites. Sternites of abdomen yellowish red. Sternites unmarked, except that the ganglionic area is faintly outlined on each. Wings as in male, except that the stigmatic

area is faintly opaque, and the veins of the fore wing and the upper half of the hind wing are yellowish brown. Tails yellowish white, joinings light red-brown. Alternate joinings wider. See Pl. 8, Fig. 1b., for appearance of apical margin of 9th sternite.

Holotype—Male subimago—Taken at Mirror Lake, near Highlands, N. C., on April 7, 1929, by Prof. Needham. No. 1078.1 in Cornell collection.

Allotype—Female imago—From Harbison's Pond, near Highlands, April 5, 1929. Same collector. No. 1078.2 in C. U. collection.

Paratypes—Five nymphs—Same data as for female imago. No. 1078.3–7 in C. U. collection.

Blasturus sp? No. 1

Nymphs greyish brown; very close to *B. cupidus* in general color but differing from this species in the number of large pectinated hairs on the maxilla, the number of teeth on the fore claw, and somewhat in the structure of the gills.

Size—Male nymphs,—body 8–9½ mm. Female nymphs, body 9–10 mm. In all the specimens the tails were broken.

Head—Whitish areas near ocelli quite prominent, especially the streak extending forward from the median ocellus. A few black reticulations on vertex of head.

Thorax—Light areas on pro-and mesonota, as in *B. collinus*. In addition, a few small black marks on the pronotum.

Legs—Femora light reddish brown, tibiae and tarsi yellow-brown. Faintly darker at joinings.

Abdomen—Light marks, one on each side of median line at anterior margin, on tergites 4–8, often rather indistinct. Tergites 1–3, and 9, usually without markings. Tergite 10 lighter in color, and with median and two lateral darker streaks. Ventrally, four lighter spots near center of each sternite and the dusky bar near the pleural fold present, but rather indistinct.

Tails—Light brown, darker at joinings. Alternate joinings wider.

From the piedmont region

Specimens taken from the piedmont fall into three new species. A large form, *B. grandis;* a somewhat smaller *B. austrinus;* and the very small *B. gracilis* are recognized in this material and described as new species.

Blasturus grandis, sp. nov.

MEASUREMENTS

	BODY	OUTER TAILS	INNER TAILS	FORE-WING	FORE-LEG
Male nymph (9 specimens)	11½–14	11–14	11–14		
Female nymph (7 specimens)	11½–16	13–18	13–19		
Male imago (9 specimens)	11–13	20–28	10–14	10–12½	8½–11
Female imago (6 specimens)	12–15	14–18	11–14	11–13½	5½–7

This is a large species, the abdomen of the male imago being predominantly yellowish with grey markings dorsally and no distinct ventral markings. Genitalia with rather deep incisure on outer margin on each side of the penes. Considerable variation in both size and color.

Nymph

Head reddish brown. Vertex and occiput mottled with black. Space between ocelli black. Yellowish white spots laterad of lateral ocelli, yellowish streak, extending to margin of labrum, forward from median ocellus. Six to seven large pectinate hairs just below crown of maxilla.

Thorax—Four white spots on each side of prothorax. See Pl. 8, Fig. 3a. Several small white spots anterior to each wing root, on mesonotum. *Legs* prominently barred with brown (in a few specimens, barring rather indistinct.) Femur with broad bar one-third from distal end; tibia brown at basal end and in center; tarsus with wide basal and narrow distal band. About 20 teeth along inner margin of fore claw; 9–10 teeth in upper row.

Abdomen—Dorsally dark brown in mature female, yellowish brown in male. A white crescentic spot on each side of median line of each tergite near center. Two (sometimes three) white marks, separated by a darker bar, on each side near pleural fold. Median dorsal line dark. In male, a triangular yellowish mark projects forward from the posterior border on each side, between median line and pleural fold. In this sex also, tergites 9 and 10 are predominantly yellow. Ventrally, male yellow, female dark red-brown. Rather indistinct whitish marks on each sternite; four grouped near center, one on each side near pleural fold.

Gills—of third pair as on Pl. 8, Fig. 13.

Tails of female dark red-brown, of male yellow-brown. Joinings of each dark brown, alternate joinings near the base being wider.

Male imago

Head—Vertex dark brown; remainder light brown. Antennae and upper part of compound eyes orange-brown.

Thorax—Pronotum dark brown. Median line and two bars near each lateral margin, black. Mesonotal shield dark red-brown margined on each side, in front of and behind each wing root, with yellowish. Mesothorax dark red-brown. Sternites dark brown. Coxae of forelegs surrounded by yellowish white.

Legs—Femur and basal third of tibia of foreleg bright orange yellow. Trochanter and coxa marked with brown. Dark brown spot at distal end of femur, on outer side. Femoro-tibial joint dark brown. Distal two-thirds of tibia, and tarsus, greyed yellow. Claws darker grey. Second and third legs with femur and tibia same color as femur of foreleg; tarsus yellow.

Wings—Main longitudinal and cross veins in all but anal region of forewing bright yellow to orange-brown. In some specimens, tendency towards anastomosis of cross veins in apical third of costal space. No cloud or other dark mark on wings. Veins C. and Sc of hind wing bright yellow, remaining veins light straw-colored.

Abdomen—Dorsally, groundwork of segments 2–7 orange-yellow, marked with yellow and greyish brown. Two prominent marks on each side of median line, from anterior margin to center of each tergite, yellow. A greyish-brown W-shaped mark surrounds these yellow bars. A brown line on each side near pleural fold. Tergites 1, and 8–10, darker brownish with same general markings. See Pl. 8, Fig. 5a. Ventrally, sternites 4–7 bright clear yellow; sternites 1, 3 and 8 greyish yellow. Anterior margin of 1 dark brown. Sternite 9 dark brown except for crescentic yellow space on posterior margin. A faint grey posterior border is often present on the central sternites. No dark bars on each side of median line. On some specimens, a grey mark is present on each side near the pleural fold. Ganglionic area may be whitish, or in some cases light orange.

Genitalia—Penes with distinct incisure on each outer margin. Appendages of penes not hood-shaped as in *B. cupidus* and *B. austrinus*, but rather of the "scarf" type. Each appendage is sufficiently long to reach to or beyond the sinus between the two limbs of the penes. See Pl. 8, Figs. 4 and 11.

Tails—Light brown. Joinings dark brown, alternate joinings darker and wider. Middle tail lighter in distal half, approximately half as long as the outer tails.

Female imago

Body reddish brown, lighter ventrally. Head yellowish. Legs light reddish brown. Veins of fore wing, and of costal margin of hind wing, orange-brown. No cloud in wings. Tails reddish brown, joinings darker. Apical margin of 9th sternite as on Pl. 8, Fig. 10. Abdominal tergites dark red-brown. On each a prominent light mark on each side of median line at anterior margin. Posterior margins and anterior lateral angles of tergites narrowly yellowish. Abdominal sternites yellowish in center and on each margin. Remainder of each light grey-brown, except for yellow indentation from anterior margin. A greyish mark near posterior margin of each, in central portion.

Holotype—Male imago—Reared. Scales Lake (on private estate near Greensboro, N. C.). March 17, 1930. No. 1075.1 in Cornell University collection.

Allotype—Female imago—Reared. Lake near Liberty, N. C., Feb. 26, 1930. No.1075.2 in C. U. collection.

Paratypes—Four male and two female imagoes. Reared. Polecat Creek, N. C., April 8, 1930; Scales Lake, March 17 and 28, 1930; lake near Liberty, March 17 and April 2, 1930. No. 1075.3–8 in C. U. collection.

Nymphs of this large species were taken at Scales Lake and Pinecroft Lakes, near Greensboro, and at a lake near Liberty. A few were also collected from Polecat Creek, south of Greensboro. Mature nymphs were found on March 13, 1930, at Scales Lake and the lake near Liberty. Most of these transformed between this date and the end of March, which times seems to be the height of the transformation period for this species. However, some nymphs taken at Pinecroft Lake early in February and kept indoors, transformed as early as Feb. 21. The length of the subimaginal stage of this species varies from 18½ to 29 hours.

Blasturus austrinus, sp. nov.

MEASUREMENTS

	BODY	OUTER TAILS	INNER TAILS	FORE-LEG	FORE-WING
Male nymph (11 specimens)	10–11½	10–15	15–16		
Female nymph (12 specimens)	11–12	12–16	13–15		
Male imago (16 specimens)	9–11½	18–29	8–12	8–11	8–10½
Female imago (11 specimens)	9–12	12–15	8–9	5	9–10

A species somewhat smaller than *B. grandis*, and darker in color, but not as dark as *B. cupidus*. Faint brownish stain in stigmatic area of fore wing of male imago. Considerable variation in color, in all stages. Light-colored males very similar to *B. grandis*. Darker forms show two dark bars on each sternite, one on each side of the medial line, projecting backwards from the anterior margin, as in *B. cupidus*. This species may be the "variety from North Carolina" placed by Eaton under *B. cupidus*.

Nymph

A light reddish-brown form, abdomen marked dorsally with yellow.

Head—As in *B. grandis*. Six to seven large pectinate hairs below the crown of the maxilla.

Thorax—Pro- and mesonota marked with black, leaving light areas. See Pl. 8, Fig. 3c, for appearance of pronotum.

Legs—Yellow to light reddish brown. In fully-mature nymphs the tarsi are often dusky, and tibiae slightly darker than the femora. In some specimens, fairly distinct bars on the legs, as is typically the condition in *B. grandis*. More frequently the legs are entirely unbanded, or show very faint dusky marks as the location of the bands. Joints darker. Small triangular brown mark often present at distal end of femur; basal end of tibia likewise brown. 20 to 21 teeth on inner margin of fore claw; about 8 in upper row.

Abdomen—Dorsally, females with reddish brown background on each tergite, marked with yellow. Males, yellow to light red background, marked with brownish grey. For color pattern, see Pl. 8, Fig. 18a. Ventrally, four white marks on each sternite near median line. Larger pair just back of anterior margin, one on each side of center, directed slightly outward. Smaller pair nearer median line at center of sternite, parallel to this line and to each other. In males, a slender crescentic white mark may be present near the pleural fold. On each sternite a blackish bar parallel to and near the pleural fold. The white crescentic mark, when present, lies outside of this dark bar. In young nymphs, the dark bars are evident, but not the white marks.

Tails—Yellow in immature stages. In mature male nymph, outer ones dark red-brown. In female, all three are light red-brown. Joinings in every case dark reddish brown, wider alternately.

Male imago

a. Light form

Head—Vertex light brown, darker on posterior margin. Basal joints

of antenna orange, filament grey. Upper portion of compound eye light orange.

Thorax—Pronotum dark brown, narrowly bordered with whitish on posterior margin, widely bordered on each lateral margin. Median line black, narrowly bordered with white. Meso-and metanota dark red-brown, margined narrowly with cream-white. Pleurites of meso- and metathorax dark brown, lighter between sclerites. Prothoracic pleurum light grey, with indistinct brown bar. Sternum dark red-brown except central portion of posterior sclerites of mesosternum, which are light brown.

Legs—Femur and tibia of fore leg light orange-yellow. Tarsus greyed yellow, coxa and dorsal aspect of femoro-tibial joint brown. Other joinings light brown. Other legs yellow, joinings light brown.

Wings—Translucent. Longitudinal veins of forewing and cross veins except in anal region, yellow-brown. All others greyish. Apical portion of stigmatic area of forewing somewhat opaque, but lacking a brown cloud. Tendency for cross veins in this area to be strongly anastomosed.

Abdomen—Very similar to *B. grandis*, except that the sternites are usually light brownish yellow, the basal half of 1 and 9 dark brown. Tergites narrowly bordered with yellowish white posteriorly. Differs from *B. grandis* principally in the presence of indistinct bars on each sternite, one on each side of median line, at anterior border. Ganglionic area usually greyish orange. A dark spot on each side of median line at center of sternite 1. A prominent greyish-brown bar, parallel to and near the pleural fold on each side, is constantly present. Posterior margin of each sternite greyish white.

Genitalia—Of the "hooded" type. No incisure on outer margin of penes, as in *B. grandis*. The appendages of the penes are shorter relatively than in *B. grandis*, not reaching to the sinus between the two limbs of the penes. See Pl. 8, Fig. 21. Genitalia light yellow in color.

Tails—Light brown, the joinings blackish brown. Alternate joinings wider.

b. Variations from the above description

Some males have the sternites of the abdomen much lighter in color, greyish white with faint yellow tinge. In some, the posterior margins of the sternites are dark grey, at least in the central part.

Darker forms often occur, in which the antennae are dark brown, and all (or the basal two-thirds) of the femur, and the tibia, of the foreleg are

red-brown. The tarsus is then greyed brown. Other legs are lighter red-brown. Tergites much darker, the background being yellowish brown and the markings dark brown. Tergites 1 and 2, and 8–10, usually solid dark red-brown. In these forms, the bars at the anterior margin of each sternite are quite prominent, being dark brown in color. Each sternite has two small dark spots near the center, one on each side of the median line. Tails very dark brown. Veins of wings darker brown.

Female imago

Light reddish brown. Head and pronotum very light greyed red, marked with black. Meso- and metanota red-brown. Thoracic pleurites and sternites lighter red-brown. Legs light red to reddish brown. Abdominal tergites with background of light tan tinged with red; darker brown markings as in male. Posterior margin of each tergite dark greyed brown. Abdominal sternites light red-brown. Dark bars near the pleural folds much smaller than in the males, and not always present. No dark bars from anterior margin on each side of median line. Ganglionic area sometimes very faint orange. Tails dark brown for a short distance basally, becoming greyish tan.

Joinings as in male. Shape of apical margin of 9th sternite as on Pl. 8, Fig. 1d.

Variations—Some females are darker dorsally, the tergites of the abdomen resembling the female of *B. grandis*. These have also a dark line parallel to the posterior margin of each sternite, and a triangular blotch on each side, next to the pleural fold.

Holotype—Male imago—Reared from nymph. Lake near Liberty, N. C., March 22, 1930. No. 1076.1 in C. U. collection.

Allotype—Female imago—Reared from nymph. Big Alamance Creek, N. C., April 10, 1930. No. 1076.2 in C. U. collection.

Paratypes—Male imagoes, 4 female imagoes—Reared. Lake near Liberty, N. C., March 3, 25, and April 2, 1930; Scales Lake, March 28, 1930; Pinecroft Lake, Feb. 19, 1930. No. 1076.3–16, in C. U. collection.

Nymphs of *B. austrinus* were taken from the lake near Liberty; from Scales Lake, Pinecroft Lake and Hamburg Lake, near Greensboro; from Big Alamance Creek at Tom's Place; and from a small stream near Spero. In 1929, the earliest date of collection was March 24, from near

Spero and at Liberty. In 1930, many almost mature nymphs were taken from Pinecroft Lake on Jan. 27. Many other collections were made during March and April, likewise in February of 1930, in the locations mentioned above. The height of the transformation period for this species, in 1929, occurred before the middle of April. In 1930, however, this period occurred from the middle to the last of March. The earliest transformations recorded were several individuals of both sexes from Pinecroft Lake, on Feb. 17, 1930.

The length of the subimaginal period, in seven females carefully observed, varied from 20 to 24½ hours. Four of these transformed in 20 hours, three required more than 24 hours.

In the case of the males, the transformation period for seven individuals was found to vary from 19½ to 22½ hours. Two required 19½ hours each; four, 22 hours each; only one required longer than 22 hours.

Blasturus gracilis, sp. nov.

MEASUREMENTS

	BODY	MIDDLE TAIL	OUTER TAIL	FORE-LEG	FORE-WING
Male nymph (8 specimens)	5–7	7–11	7–9		
Female nymph (11 specimens)	6–7½	6–10	6–9		
Male imago (6 specimens)	6–7	11–13	12–15	6½–7½	5½–6½
Female imago (6 specimens)	5½–6	6½–8	7–8	3–4	5½–6

A small species, in which the *middle tails of the imagoes almost or completely equal the outer tails in length.* Male imagoes have abdominal sternites 3–6 translucent white. Female imagoes are very light red in color. Forelegs of males equal or exceed the body in length. Nymphs light reddish brown, yellowish ventrally.

Nymph

Head light reddish brown. Ocelli and compound eyes black. Whitish area cephalad of median ocellus, laterad of lateral ocelli. Antennae yellowish white, light brown on first three basal segments. Sutures of head yellowish white. *Mouthparts* very similar to others of the genus. 5 large pectinate hairs just below upper margin of maxilla.

Thorax—Dorsally, light reddish brown. Pleura and sternites lighter shade of same. Pronotum marked with a long white stripe on each side near pleural fold. Near median line anteriorly a small white spot; another near center of each side. On each side a whitish mark anterior

to wing roots on mesonotum, another crescentic mark one-third from posterior spine. Median dorsal line narrowly yellowish white.

Legs—In young nymph, yellowish white. In mature nymph, very light reddish brown dorsally, yellow ventrally. Darker at joinings. On some, very indistinct darker bar on femur. Claw of first leg with 18 teeth on inner margin, 5 in upper row.

Abdomen—Light reddish brown dorsally, except 10 and posterior half of 9, which are yellow. Some mature male nymphs are yellowish red dorsally. On each tergite, four white spots. One on each side of median line at anterior border, and a larger one in or just posterior to each anterior lateral angle. Anterior margin of each sternite, and a very small triangular mark at ganglionic area of each, dark brown.

Gills greyish white, tracheae purple-black. First gill lacking lateral branches from main tracheae. See Pl. 8, Fig. 10, for third pair of gills.

Tails yellowish white, joinings reddish brown. Alternate joinings slightly wider.

Male imago

Head—Orange. Upper part of compound eyes orange; small basal portion black. Ocelli amber, black-ringed at base. Basal segments of antennae yellow; filament grey.

Thorax—Pronotum yellowish white, with large brown spot occupying most of dorsal area on each side of the wide median yellowish portion, and an oblique brown band across lateral margin. Mesonotum and metanotum reddish brown. A triangular creamy white patch at anterior margin of mesonotal scutellum. Pleura yellow with brown patches. Sternites brown. White ring around base of each leg.

Legs—Forelegs as long as or slightly longer than body. Coxa and trochanter light brown. Femur and sometimes tibia light yellow or yellowish brown. Tibia and tarsus white, except brown basal end of tibia. Second and third legs yellowish white. Claws margined with purplish brown.

Wings—Longitudinal and main cross veins in all but anal region of forewing light brown. Other veins white or very faintly yellow. Cross veins in costal space between humeral vein and bulla very indistinct. In apical portion, cross veins readily visible; some slight tendency toward anastomosis. Apical portion of cells C and Sc with faint whitish cloud. Hind wing rather small.

Abdomen—Segments 1, 9 and 10, and tergite 8, reddish brown. Segment 2 and tergite 7 olive brown, except a white border on each margin.

Anterior two-thirds of tergite 3, and anterior half of tergites 4–6, silvery white. Posterior margins of these tergites narrowly white; remainder of each olive-brown. An oblique black dash in center of pleural fold on each side of tergites 1–6; black bar parallel to pleural fold on entire length of segments 7–9. The above applies to light-colored specimens. Darker forms have tergites 3–6 similar to 2 above, and 7 somewhat darker. Three small white spots clustered together next to the pleural fold are present on some specimens, on tergites 1–7.

Sternites 2–7 on light specimens, and 2–5 on darker forms, translucent white. Remaining sternites very light reddish brown. Posterior margin of 9 white.

Genitalia—Forceps white, penes and forceps base yellowish. Forceps 4-jointed; fourth joint very small, third swollen at distal end. Processes of penes not as long as angle between limbs of penes; the spine at the distal end very short and inconspicuous. See Pl. 8, Fig. 14.

Tails—Middle tail only slightly more slender than outer ones, and equalling or approximately equalling them in length. Greyish white, joinings narrowly red.

Female imago

Slightly smaller than male. Head, thorax and abdomen light red, the thorax and abdominal tergites being slightly darker than the other parts of the body. Femora very light red, tibiae and tarsi yellowish. All veins except along the costal margin of the forewing white or very faintly yellowish. In other respects similar to male.

Holotype—Male imago—Reared from nymph, Hamburg Lake near Greensboro, N. C., April 28, 1930. No. 1077.1 in C. U. collection.

Allotype—Female imago—Same data. April 22, 1930. No. 1077.2 in C. U. collection.

Paratypes—5 male imagoes. 5 female imagoes—Same data. April 22–28, 1929; April 28, 1930. No. 1077.3–12 in C. U. collection.

The slender and graceful nymphs of this small species were collected mainly from Hamburg Lake, 11 miles north of Greensboro. A few were taken likewise from a tributary of Big Alamance Creek at Tom's Place. In the former locality they were most numerous among a growth of Potamogeton on the northeast shore of the pond. Nearly mature nymphs were taken here on April 5, 1929. A female transformed on April 10, and many others from April 22 to 26. In 1930, mature nymphs

were collected on April 17. The first of these transformed on April 20, others from April 28 to May 4.

Occasionally a nymph transformed as early as 10:30 a.m., but most of those observed came out between 2 and 5 p.m. In a period of relatively cool weather, two males each spent 46½ to 47½ hours in the subimago stage, while a third required 50 to 51¼ hours to complete its transformation. One female transformed in exactly 24 hours, another in 41½ hours, the latter in warm weather. With the exception of the one female transforming in 24 hours, the periods spent as subimagoes by individuals of this species are much longer than for the other two species from the piedmont. See notes following descriptions of these.

From the coastal plain region

Of the species collected from the coastal plain region, one is represented by nymphs alone, and is designated as *B.* sp? No. 2. Two subimagoes and one female imago taken by Prof. Needham from Lenoir Co. on April 11, 1929, are so similar to *B. gracilis* as to be considered of that species, at least until more adequate material is at hand.

From nymphs of a third species, one male subimago was reared. This is apparently a new species, and is known as *B. intermedius*.

Blasturus intermedius, sp. nov.

Size—Male nymph—body 8–9 mm; outer tails 9–12, inner tail 8 mm. Female nymph, body 7½–8 mm; tails broken. Male subimago, body 8 mm; outer tail 10, inner 8½; foreleg 5¼; forewing 7½ mm.

Nymph

Body red-brown.

Head brown. White spot laterad of each lateral ocellus. White streak forward from median ocellus to margin of clypeus. Two white spots on median line of clypeus, one such spot on labrum. Four large pectinate hairs just below crown of maxilla.

Thorax—Prothorax as on Pl. 8, Fig. 3b. No definite light markings on meso- or metathorax. Legs definitely barred with dark brown. Bar on femur one-third from distal end. Tibia dark at basal end, bar across center. Tarsus barred at each end. Claw of foreleg with 16 teeth on inner margin, 8 in upper row.

Abdomen—Wide dark mark along median line of each tergite. On 7–9, tending to divide toward posterior margin into two forks. White

spots on each side of median line large, quite prominent. No evident markings on sternites.

Gills of third pair as on Pl. 8, Fig. 7. First pair with few or no lateral branches.

Tails straw colored to light brown, joinings red-brown. Alternate joinings wider in basal half.

Male subimago

Head—yellowish brown. Eyes and antennae as in other species of the genus.

Thorax—Pronotum brown, margined with yellow. Mesonotal shield dark red-brown, with three longitudinal white lines; mesonotal spine and area anterior to it, white. Metatotum like pronotum. Ventrally, center of prosternum, anterior and central sclerites of posterior portion of mesosternum dark brown. Remainder yellowish brown.

Legs—Orange-brown. Dark brown marks on trochanter and femorotibial joints. Tarsi somewhat dusky brown, joinings darker.

Wings—Dusky brownish grey.

Abdomen—Tergites yellowish brown. Each with black streak on median line; black mark on each side near pleural fold; an oblique black mark in pleural fold, except on 8–10. 1 and 2 likewise with transverse semicircular dark line near center. Posterior margin of each dusky. Sternites lighter yellow-brown; very indistinct grey lines in anterior half of each, bordering median line.

Genitalia as on Pl. 8, Fig. 19.

Tails—Light brown, joinings dark brown. Alternate joinings wider.

Holotype—Male subimago—Reared from nymph. Tributary of Cape Fear River, near Buies Creek, N. C., April 1, 1930. No. 1080.1 in C. U. collection.

Paratypes—Five nymphs—Same data. No. 1080.2–6 in C. U. collection.

Blasturus sp? No. 2.

Another small species, differing from *B. gracilis* in color, structure of gills, number of teeth on fore claw, and number of large pectinate hairs on maxilla. Body dark greyish brown.

Nymph

Size—Male nymphs, body 5–6 mm; female nymphs, body 5½–6 mm. Tails of all specimens broken.

Head—Vertex light brown, sutures white; no dark marks. Dark brown area around each antenna. White areas on sides of each lateral ocellus and anterior to median ocellus. Six large pectinate hairs below crown of maxilla.

Thorax—Median dorsal line white. Pronotum mottled with white, the principal markings being as follows. Large crescentic mark halfway to lateral border on each side; small mark near anterior margin, on each side of median line; oblong blotch just posterior to center of each side of sclerite; crescent at center of posterior margin; anterior lateral angles white. Mesonotum with indistinct longitudinal white bar parallel to median line, on each side.

Legs—Light yellowish grey. No distinct dark bands, but some specimens show faint darker regions in center of femur. Joinings narrowly brown. Claw of foreleg with about 16 teeth on inner margin, 4 in upper row.

Abdomen—Dorsally greyish brown, with indistinct white marks on each tergite. One on each side of median line at anterior margin; pleural borders of 3–8 white, except posterior lateral angles. Tenth tergite largely yellowish white. 8 and 9 whitish at center of posterior margin, on median line. Ventrally, a darker line on each side of each sternite, parallel to pleural fold. No other markings.

Gills—Third pair as on Pl. 8, Fig. 15. Faintly tinged with brown; tracheae black. Gills of first pair lacking lateral branches from the two main divisions of the trachea.

Tails—Yellowish white, narrowly reddish brown at joinings.

These nymphs were collected from two small tributaries of the Cape Fear River near the little town of Buies Creek on April 1, 1930. No adults were reared.

GENUS TRICORYTHUS Etn. 1868

Tricorythus sp?

A few nymphs of this genus were taken in the piedmont area, in a small stream near Spero, on March 24, 1929. None were reared, nor were any others of this genus found, in any area of the state.

GENUS CAENIS Stephens 1835

Caenis diminuta Wlk.

Nymphs of this species were found in the mud and trash along the shore of Hamburg Lake,—a small artificial pond north of Greensboro,

N. C. Imagoes were reared from these nymphs, emerging on April 10–25, 1929, and on April 27, 1930. This species was taken at no other station.

Caenis sp?

A single nymph of another species was collected from Big Alamance Creek at Tom's Place, on April 13, 1930. It differs from the nymph of *C. diminuta* in 1) being much more slender of body; 2) bandings of legs less prominent; 3) prothorax more definitely widened at the anterior border.

No other Caenis nymphs nor adults were collected.

GENUS EURYCAENIS Bengtsson 1917

Eurycaenis nitida, sp. nov.

The interesting three-horned nymphs of this species were taken at several stations in the Appalachian region. A single female imago was reared from these nymphs.

This species may possibly be synonymous with *E. pallida* Ide, of which only the male imago is known. However, the female imago is somewhat larger than the measurements given for *E. pallida*, and does not agree in color with the description of the male of that species. It seems best, therefore, to consider it a new species. The nymph differs from the description of *E. lacustris* (Needham), in N. Y. State Coll. For. Tech. Pub. No. 9, 1918, in its larger size, its darker color, different color pattern, the presence of conspicuous tubercles on the lateral margins of the prothorax, the narrower head, the absence of a dark band on tibia and tarsus, and the unbanded tails. A description of female imago and nymph follows.

MEASUREMENTS

	BODY	TAILS	FOREWING	FORELEG
Female nymph (5 specimens)	7–7¼	3–3¼		
Female imago (1 specimen)	4½	3	5	2

Female imago with dark reddish brown mesonotum. Abdominal segments 1–6 purplish, posterior segments yellowish. Sternite 1 very wide; 2–6 very narrow, 7 and 8 wider, but not as wide as 1. Tergites 1–6 very narrow, 7–9 wide. Pleural filaments purple. Femora light

olive brown, tarsi whitish. Wings purplish in proximal half of costal border. Tails white, unbanded, hairy in distal half.

Nymph possessing a tubercle on each lateral margin of the prothorax. Color in general dark reddish brown, lighter ventrally; tergite 9 greyish white; legs and tails yellowish white.

Female imago

Head—Light yellowish brown, except median carina and portion of vertex anterior to lateral ocelli, which are purplish black. Compound eyes black. Ocelli large; black basally, pearl-grey at vertex. Antenna whitish.

Thorax—Prothorax dark purplish brown, somewhat lighter on lateral margins. Mesonotum very wide and long; dark reddish brown, a lighter strip on each side of the median line. Sutures purplish black. Metanotum purplish, pleura light brown except between second and third leg, where the color is dark reddish brown. Ventrally light brown shaded with purple, the sutures purplish black. Areas around median coxae yellowish brown. Anterior portion of mesosternum most heavily shaded with purple.

Legs—Foreleg short; second and third legs relatively long, each being about 3 mm. in length, and extending to or beyond the tip of the abdomen. Femora of last two pairs about as long as tibia and tarsus combined; fore femur longer than combined tibia and tarsus. Femora, and tibia of foreleg, light olive brown margined with dark brown. Tibiae of second and third legs yellowish. Tarsi whitish.

Wings—Greyish white. Veins in proximal half of costal border purplish. Main longitudinal veins purplish grey in their basal portions, fading into greyish white distally. Wing as on Pl. 12, Fig. 5.

Abdomen—Tergites 1–6 very short; 7–9 longer. Tergites 1–3 purplish black, 4–6 purplish grey in central portion; the lateral borders of each are greyish white, with posterior margins lavender. The peculiar long filamentous pleural processes are purplish. Tergites 7–9 greyish yellow, the posterior borders and median line greyed lavender. Tergite 10 yellowish brown, purplish on median line and posterior border. Ventrally, sternite 1 very long, sternites 2–6 very short; 1–6 purplish, finely mottled with very tiny light dots; posterior borders darker purple. Two larger light spots posterior to center of sternite 1, rather indistinct. Lateral margins shading into greyish lavender. Tergites 7–9 yellowish, 8 shaded with brown. Apical margin of 9th sternite extending out to a blunt point at the center. See Pl. 12, Fig. 23.

Tails—Greyish white, faintly washed with lavender at the base. In distal half, set with numerous whitish hairs.

Nymph

Head—Narrower than any portion of the body except the last three abdominal segments. Clypeus, genae and area around compound eyes yellowish brown. Vertex blackish brown. Occiput dark red-brown, median line yellow. The three ocellar tubercles light brown. Compound eyes black margined with amber. Antenna yellow to yellowish brown. Mouthparts as on Pl. 12, Figs. 2, 7, 8, 10, 25 and 27.

Thorax—Pronotum dark reddish brown, shaded with purple laterally. A triangular portion at center of posterior margin lighter brown; black area in center at median line and on each side. A prominent tubercle on each lateral margin, anterior to the center. Anterior margin somewhat incised. Sclerite much narrower at anterior than at posterior margin, so that the prothoracic pleura extend out from beneath the pronotal border as rounded prominences. Mesonotum dark reddish brown, the median line and region on each side of this on the dorsum marked irregularly with black. Blackish marks anterior to wing roots. Pleura reddish brown, a purple-black spot posterior to foreleg and anterior to middle leg. Ventrally, light reddish brown with wash of purple.

Legs—Foreleg relatively short, 1¼ to 1½ mm. in length. Second and third legs long, each measuring about 4 mm.; the third very slightly exceeding the second in length. Yellow, the tibiae and tarsi lighter than the femora. Claws amber.

Abdomen—Dorsally reddish brown, tergite 9 yellowish distally, yellowish brown basally. Elytroid gills very dark red-brown; the long hairs of the other gills which protrude from beneath these covers are greyed purple. Spinous lateral projections and area next to pleural fold purplish brown. Posterior margins of tergites 8 and 9 narrowly yellow. Tergite 10 very dark brown except for crescentic yellow mark at center of anterior margin and a yellow posterior border.

Ventrally, reddish brown except distal half of sternite 9, which is yellow. Sternite very long and tapering. On 2–8, a dark brown transverse mark from pleural fold almost to median line on each side, parallel to but toward center from the anterior margin.

Tails—Yellow basally, shading into amber brown in distal portion. Margined with yellowish white hairs.

Holotype—Female imago—Reared. Rocky Broad River, N. C., July 2, 1930. No. 1089.1 in C. U. collection.

Paratypes—Four female nymphs—Rocky Broad River, N. C., July 2, 1930; Bald Creek, N. C., July 6, 1930; Little River, near town of Cedar Mt., N. C., July 12, 1930; Tributary of Davidson River, N. C., July 9, 1930. No. 1089.2–5 in C. U. collection.

Besides the localities listed under the paratypes, these nymphs were found at Toxaway River, near the big falls below the town of Lake Toxaway, on July 16, 1930. These latter nymphs were immature, and are therefore not included among the paratypes.

Nymphs of this species appear to differ somewhat from those of *E. lacustris*, in their habitat. Prof. Needham says of the latter species, "This seems to be in America an inhabitant only of lakes, though its European counterpart above mentioned (*E. harrisella*) is not." As my specimens of *E. nitida* were taken from small rivers and mountain streams, they would seem to be closer to *E. harrisella* (Curtis) in their manner of life than to *E. lacustris*. The nymph of *E. pallida*, the only other species of this genus, is not known.

GENUS EPHEMERELLA Walsh 1862

Key to Species of Ephemerella Nymphs found in North Carolina

Note: That portion of the key which deals with the *bicolor-lutulenta* group is taken from Dr. McDunnough's recently published key on that group of the genus Ephemerella.

1. Gills present on segments 3–7; not operculate.....2
   Gills present on 4–7; operculate or semi-operculate on segment 4.....16
2. Femur I with serrations or spiny outgrowths on anterior margin; frontal horns present, but may be inconspicuous.....3
   Femur I without such serrations or spines; frontal horns lacking.....9
3. Frontal horns long and conspicuous, extending beyond anterior edge of frontal shelf.....4
   Frontal horns short and often inconspicuous, not reaching anterior edge of frontal shelf.....6
4. Projection on distal end of fore tibia (tibial spine) short and blunt, not turning outward. Frontal horn strongly incurved, almost semilunar *cornutella*
   Tibial spine long (reaching at least to middle of tarsus) and sharp at tip. Frontal horns less strongly curved.....5
5. Tibial spine extending well beyond middle of tarsus; its distal third curving sharply outward. Spine below median ocellus sharp.....*longicornis*
   Tibial spine not extending beyond middle of tarsus, curving out gradually from base. Spine below median ocellus rather blunt.....*cornuta*

6. Occipital tubercles present.....7
Occipital tubercles absent.....8
7. Tubercles present on thorax.....*tuberculata*
Tubercles not present on thorax.....*conestee*
8. Dorsal spines present; nymph much flattened, hairy.....*wayah*
Dorsal spines absent; nymph only slightly flattened, not conspicuously hairy; prothorax broad, yellowish white.....*lata*
9. Occipital tubercles present.....sp? No. 2
Occipital tubercles absent.....10
10. Dorsal spines present and conspicuous.....11
Dorsal spines absent or inconspicuous.....13
11. Nymph large (7–11 mm.); margins and sometimes upper surface of fore femur thickly set with short tubercles.....*rotunda*
Nymph small (not exceeding 5½ mm.); no such tubercles on fore femur.....12
12. Body semi-depressed. Lateral extension of 9th abdominal segment extending beyond end of 10th segment. Ventrally a row of dark lines on each side *serrata*
Body cylindric, compressed. Lateral extension of 9th abdominal segment not reaching to end of 10th. Ventrally, four dark marks on each sternite, as well as a row of dark lines on each side.....*serratoides*
13. Maxillary palp absent.....*deficiens*
Maxillary palp present.....14
14. Postero-lateral angles of abdominal segments blunt to rounded....*dorothea*
Postero-lateral angles of abdominal segments sharp spinous processes.....15
15. Slender small nymphs, 5–7 mm. in length. No indication of dorsal spines *catawba*
Stout larger nymphs, 7½–10 mm. in length. Faint traces of dorsal spines, very inconspicuous.....*inconstans*
16. Gill on segment 4 semi-operculate, only partially covering remaining gills sp? No. 1
Gill on segment 4 fully operculate, covering remaining gills.....17
17. Width between dorsal tubercles on abdominal tergites 5–7 much less than the width of the respective tergites on the median line; large species, occipital tubercles strongly developed.....*temporalis*
Width between dorsal tubercles on abdominal tergites 5–7 more or less equal to the length of the respective tergite on the median line; occipital tubercles lacking in male, much reduced in female.....*minimella*

NOTES ON THE GROUPING OF THE EASTERN SPECIES OF EPHEMERELLA

On the basis of similarity of male genitalia or of structural characters of the nymphs, or of a combination of these characters, the eastern species of the genus Ephemerella seem to fall into natural groups within the genus.

I. Bicolor-lutulenta group

Nymphs of this group possess gills on segments 4–7 only; gill on segment 4 elytroid, covering gills on 5–7. Dorsal spines present on abdo-

ment, and prominent; lateral margins of abdomen much flattened, and widely prolonged into spinous processes; tubercles usually present on occiput. Maxillary palp lacking; no spines on front margin of fore femur. The great similarity of the male genitalia of the species in this group serves to confirm the above grouping, based on nymphal characters.

The nine species included in this group have been adequately dealt with by Dr. McDunnough, in his recent paper on this group (Canad. Ent. **63**: 30–42, and 61–68. 1931.). These nine species are; *E. prudentalis* McD.; *E. temporalis* McD.; *E. funeralis* Mc.D.; *E. lutulenta* Clemens; *E. coxalis* McD.; *E. minimella* McD.; *E. bicolor* Clemens; *E. aestiva* McD.; and *E. verisimilis* McD.

II. Invaria group

On the basis of the male genitalia, this group falls into two subdivisons. In the first subdivision, the distal portion of the second joint of the forceps is enlarged. To this division belong the species *E. invaria* Etn.; *E. norda* McD.; *E. rotunda* Morgan; *E. dorothea* Needham; *E. subvaria* McD.; and *E. fratercula* McD. (*E. vernalis* Bks. is said to be synonymous with *E. rotunda* Morgan; it falls in this subdivision.)

To the second subdivision belong those species in which the second joint of the forceps is not enlarged distally. *E. excrucians* Walsh (the species recognized by Dr. McDunnough under this name, and *E. semiflava* McD., are members of this subdivision. (Dr. McDunnough thinks these species may be synonymous.)

The nymph of *E. fratercula* is as yet unknown. The known nymphs are rather cylindric of form; possess gills on segments 3–7, neither operculate nor semi-operculate; lateral margins of abdomen somewhat depressed and produced into spines; dorsal abdominal spines present in some, but absent in others; head and thorax without tubercles. They are generalized forms.

III. Fuscata group

Nymphs of this group possess frontal horns, well developed in some and barely noticeable in others; and spines on the front margin of the fore femur. The nymphs of the eastern species seem to fall into three subdivisions within this group.

In the first subdivision, the body is more compressed than depressed, though a tendency toward depression is apparent. No tubercles are

present on head or thorax, and no dorsal abdominal spines. Here belong *E. cornuta* Morgan; *E. depressa* Ide; *E. cornutella* McD.; *E. lata* Morgan; and the new species *E. longicornis*. (*E. inflata*, which would fall here, is said to be synonymous with *E. lata*.)

Nymphs of the second subdivision are moderately depressed in body form; possess tubercles on vertex, occiput and usually on the thorax; and have dorsal abdominal spines. To this subdivision belong *E. tuberculata* Morgan and the new species *E. conestee*.

Nymphs of the third subdivision are much depressed in body form; dorsal abdominal spines are present, but minute and inconspicuous; all femora much flattened; antennae set in notches on each side of the broad frontal shelf; occipital tubercles very minute or absent; abdomen hairy ventrally; no tubercles on thorax. To this subdivision belong the two eastern species *E. fuscata* McD. and the new species *E. wayah*. The nymph of the western species *E. doddsii* Needham shows the same modifications carried to a greater development. (*E. bispina* Needham, which would fall here, may be synonymous with *E. fuscata*.)

The male genitalia of this group, while not as closely alike as are those of the *bicolor-lutulenta* group, nevertheless show a general resemblance one to another.

IV. Simplex group

Nymphs of this group agree in having the gills present on segments 4–7 only, the gill on 4 being semi-operculate and partially covering the gills posterior to it; and in having the lateral margins of the abdominal segments depressed and much prolonged into wide flat spines. Two subdivisions are evident, however.

Nymphs of the first subdivision have rather cylindric bodies; femora slender, compressed and without spines; dorsal spines present but small; prominent thoracic tubercles and short inconspicuous occipital tubercles. *Ephemerella attenuata* McD. belongs here.

To the second subdivision belong nymphs having bodies depressed or partially depressed; femora less slender and less compressed, the fore femur enlarged at the center, but without spines on the front margin; no thoracic tubercles; occipital tubercles, if present, very minute; no dorsal abdominal spines. To this division belong *E. simplex* McD. and the new nymph from N. Carolina, Ephemerella sp? No. 1.

The nymph of *E. molita* McD., which species Dr. McDunnough places in this group on the basis of the male genitalia, has not been described.

V. Serrata group

On the basis of the male genitalia, Dr. McDunnough places the four species *E. serrata* Morgan, *E. sordida* McD., *E. frisoni* McD., and *E. serratoides* McD., in this group.

Nymphs of *E. serrata* and *E. serratoides* agree in having partially depressed body form; gills present on segments 3–7, neither operculate nor semi-operculate; lateral margins of abdominal segments depressed and much prolonged into wide flat spines: dorsal abdominal spines present. *Ephemerella serratoides* is described (McDunnough, Canad. Ent. **63**: p. 83) as lacking both occipital and thoracic tubercles, while *E. serrata* has tubercles on the thorax. The nymphs of *E. sordida* and *E. frisoni* seem not to have been described. (Dr. McDunnough includes *E. deficiens* Morgan in this group, also.)

VI. Species which do not seem to fall into the above groups

a. E. septentrionalis McD.

Nymph more closely allied to those of the *invaria* group than to any others, but strikingly different from any others known in the possession of very long legs and an extremely attenuated body. Nymph lacks dorsal spines on the abdomen; has very inconspicuous occipital tubercles; no thoracic tubercles; legs very long and slender; lateral margins of abdomen depressed and slightly prolonged into spinous processes. The genitalia also are unlike those of the other groups thus far considered. (Dr. McDunnough considers this species as a "slight modification or development" of the *invaria* group, along with the two other species *E. needhami* McD. and *aurivillii Bngtssn.*)

b. E. deficiens Morgan.

While Dr. McDunnough places this species in the *serrata* group, as already noted, I am not yet convinced that it belongs there. In body form of nymph and in genitalia of the male imago, it seems to me to be close to *E. tibialis* McD., a western form. It differs in the nymphal stage from all other known nymphs except those of the *bicolor* group, in the complete absence of the maxillary palp. The nymph lacks dorsal spines; has neither occipital nor thoracic tubercles; gills present on 3–7; lateral margin of abdomen somewhat depressed; spinous processes much as in the *invaria* group; and tails with prominent spines at the joinings.

c. E. consimilis Walsh.

Nymphs unknown; determination of the imago and its relation to other members of this genus uncertain, since the only type specimen has been destroyed.

d. E. needhami McD.
E. excrucians Needham (nec Walsh)

The male genitalia of this species, as figured by Prof. Needham (N. Y. State Mus. Bull. **86**: Pl. 10, fig. 8) seem somewhat different from those of any other known species of Ephemerella, but are probably nearest *E. septentrionalis*. The nymph figured with the description of this species belongs quite certainly to a different species, one of the *bicolor* group. It is therefore advisable to consider the nymph of the above species unknown.

As I have not had the opportunity to examine the specimen of *E. excrucians* in the Cambridge museum which Dr. Banks has selected as the lectotype of this species (see McDunnough, Canad. Ent. **57**: 171), I am here accepting Dr. McDunnough's determination.

e. E. bispina Needham

This species may be a member of the *fuscata* group.

THE GENUS EPHEMERELLA IN NORTH CAROLINA

This genus was better represented in all three of the geographical divisions of the state than was any other except Heptagenia. Of the material collected, five species are new, and are herein described. Eleven others have been positively identified and two others tentatively. There remain unidentified several species of the *bicolor-lutulenta* group, two of which have been reared but are represented by insufficient material, the others being represented by nymphs alone. Besides these, two species of nymphs are described but not named, as they have not been reared, and may prove to be nymphs of already described species known only in the imago stages.

Dr. McDunnough was kind enough to examine some of the specimens, concerning the identification of which I was in some doubt. His help was especially useful in the difficult *bicolor-lutulenta* group, on which he has recently published an excellent paper (Can. Ent. **63**: 30–42, 61–68).

Coastal plain region

The *bicolor-lutulenta* group is represented in this area by several nymphs and imagoes collected by Prof. Needham in April 1929, and a few nymphs of my own collecting, in April of the following year. One species was reared, but could not surely be identified, as only females were obtained.

Ephemerella minimella McD.?

Dr. McDunnough thinks that the specimens collected by Prof. Needham from Burncoat Swamp may be of the above species.

Piedmont region

Ephemerella dorothea Needham

Collected from the following places. Big Alamance Creek at Tom's Place, April 4, 1929, from which imagoes emerged April 25 to May 1; Caraway Creek near Sophia, April 20, 1929, imagoes emerging April 22–May 13; lake near Liberty, March 24, 1929; tributary of the Dan River at Cascades, May 12, 1929, imagoes emerging May 13; tributary of the Reedy Fork River near Guilford Battleground, April 20, 1930; and from a small creek near Tabernacle Church south of Greensboro, May 1, 1930.

The yellowish-white subimagoes of this species generally emerged between 7 and 8 p.m. When reared indoors in open dishes, they flew at once upward toward the ceiling light, and could be easily collected. While no exact records were kept of the subimaginal stage of this species, several of my notes indicate that more than 24 hours was spent in this stage.

Ephemerella deficiens Morgan

From nymphs collected in Big Alamance Creek on May 17, 1929, a male and female imago emerged on May 22.

Ephemerella temporalis McD.

The large sluggish nymphs of this lake-inhabiting species were first taken at the lake near Liberty on April 23, 1929. The first of these, a male, transformed April 28. Dr. McDunnough verified my identification of this species.

Bicolor-lutulenta group is represented in the piedmont also, by two unidentified species, both of which were reared, but very little material of each was taken. One of these Dr. McDunnough thinks, on the basis of what little material I sent him, may be *E. verisimilis* McD. It was collected in the Uharie River, Apl. 3, 1929.

Ephemerella inconstans, sp. nov.

MEASUREMENTS

	BODY	TAILS	FOREWING	FORELEG
Male nymph (8 specimens)	8–10	4½–6		
Female nymph (11 specimens)	7½–11	4–7		
Male imago (13 specimens)	8–9½	9½–13	8–9	7–9
Female imago (8 specimens)	6–10½	9–12	8–10½	3–5

A member of the 'invaria' group, the second joint of the forceps enlarged distally. Quite close to *E. rotunda*, but even in light specimens, more definitely marked with brown than that species, the legs and tails somewhat darker. Differs from *E. subvaria* in the lighter venation of the wings and the dark marks bordering the pleural folds. Abdomen of male appears to be ringed with purplish brown, due to the whitish posterior margin of each segment. Pleural fold margined on each side by a purplish-brown streak. Ventrally, a short dark bar and a dark spot on each side of each sternite, near the center. Posterior segments yellowish brown. Tails and legs variable in color. Penes with fewer spines than in *E. rotunda*.

Apparently two varieties, a large and a small one,—which do not seem to exhibit good structural differences other than size. See notes following description. Considerable variation in color, of both nymphs and imagoes.

Nymph very much like *E. rotunda* in general appearance. Differs from that species in that the dorsal tubercles are very minute, the spinous lateral extensions of the abdomen are more rounded on the outer margin and not incurved at the tip, and in having more serrations on the inner margin of the claw. Whole body finely mottled with tiny dots.

Male imago

Head—Light brown. Upper portion of compound eyes light orange. Antennae pale in light forms, light brown in dark forms.

Thorax—Pronotum light brown, often a dorsal median light streak. Posterior lateral angles light yellowish. Mesonotum yellowish to light brown; spine brown, margined with dark red-brown. Pleura light brown, sutures cream colored. Ventrally brown, darkest at center of mesosternum. In dark forms, dark reddish brown in this portion.

Legs—In light forms, yellowish white, coxa and trochanter light brown. Purplish streaks in distal portion of femur, light brown at base of tibia. In dark forms, femur and tibia of foreleg light brown, tarsi lighter. Other legs yellowish to light yellowish brown.

Wings—Longitudinal veins in basal half of costal border yellowish. Other veins of forewing very light yellowish brown. Stigmatic area opaque whitish.

Abdomen—Tergites 2–4 light purplish-brown; narrow median whitish line, posterior borders and posterior lateral angles greyish white. Tergite 1 brown on anterior and lateral margins, the central portion greyish lavender. 5–7 much like 2–4, but the brownish area much reduced and the light portion increased in size. On some, a brown longitudinal line between the central patch and the pleural fold. 8–10 washed with yellowish brown; median light brown line; center of each side with brownish patch. On each tergite, a purplish-brown line borders the pleural fold, and one or more short dark dashes are present near the stigma.

Ventrally, sternites 1–5 greyish, washed with lavender; a dark brown line on each paralleling the pleural fold. 6–10 yellowish brown, streak by pleural fold less evident. Anterior border of sternite 1 narrowly brown, lateral area widely of same color. All sternites narrowly white on the posterior margins. Ganglionic area of each sternite whitish. Two dark dots near center of sternite 1, one on each side of median line. Similar dots on succeeding sternites except 9; likewise on each of these a dark dash on each side, laterad and anterior to the dark dot.

Light forms similar in pattern but lighter in color, the posterior margins of the segments wider. However the dark bars near the pleural fold and the stigmatic spots near it on each tergite are sometimes more prominent than in dark forms. Edge of pleural fold whitish, in some specimens.

Tails—In dark forms, light brown in basal third, shading to light tan distally. Each joining ringed with purplish brown. In light forms, greyish to light tan throughout length; joinings as in dark forms.

Genitalia—Second joint of forceps enlarged distally. Penes quite similar to *E. rotunda*, but with fewer spines. Some variation in number

and location of spines, but generally a group of three on each side, and one on each side near the basal portion. Two specimens have also a single short spine on each side of the center on the distal margin. See Pl. 9, Figs. 4 and 23.

Female imago

Differs from the male as indicated.

Head light yellow in light forms, light brown in others. Ocelli ringed at base with purplish-black. Antennae purplish in basal two-thirds, white distally.

Thorax—Pronotum yellowish to light brown, a lavender streak in center of posterior margin and one on each side of center, on anterior margin. Mesonotum yellow, spine and metanotum shaded with purplish brown. Pleura yellow. Ventrally light yellowish brown, a darker brown spot at center of mesosternum.

Legs—Yellowish to light yellowish brown.

Wings—Longitudinal veins light yellow.

Abdomen—Greyish yellow, segments 6–10 yellowish brown, these marked ventrally with darker brown. Eggs impart reddish to purplish brown tinge. Pleural fold greyish; not bordered with dark streaks in light forms, but in dark forms similar to male. Faint dark dots as in male, in dark forms, often absent in light ones. Posterior margin of 9th sternite as on Pl. 9, Fig. 25b.

Tails—Light tan, joinings very faintly darker in some light forms. Dark forms similar to light males.

Nymph

General shape similar to *E. rotunda*, but somewhat less robust. Varying in color from light yellowish brown to dark mahogany brown. Body finely mottled with numerous tiny yellowish dots.

Head—Basal half of first joint, all of second, and first three or four succeeding joints, dark brown; remainder whitish. Yellowish transverse band between and laterad of lateral ocelli; yellowish marks cephalad of the median ocellus, and along the inner margin of each compound eye.

Thorax—Pronotum yellow at each lateral angle and on median line. Triangular blotch on posterior margin at each side of center (not always present), and another on anterior margin between median line and lateral margin. Other smaller light spots irregularly placed. Mesonotum with white median line, on many specimens. Large yellow dots

irregularly placed, anterior to wing roots. Ventrally, yellowish with numerous small brown dots.

Legs—Brown to dark brown, barred with yellow. Femur yellowish at each end and near center. Tibia yellowish at distal end, also a large patch near basal end. Tarsus yellowish except for dark brown bar one-third from basal end. Third claw as on Pl. 9, Fig. 26.

Abdomen—Median yellowish dorsal streak on most specimens. Flattened lateral margin beneath gills, on 3–7, yellowish white. Very dark brown streak on these segments, at inner edge of the yellow margin. Whitish spot at location of each minute dorsal spine. Lateral spinous projections more rounded on outer margin than in *E. rotunda* (see Pl. 9, Fig. 24), the end spines not incurved. Black streak across center of each process. Margins serrate. Ventrally, an indication of a yellowish median line, also a dark line on each side nearer the margin Some nymphs have also a whitish mark at the anterior margin on each side, halfway to the pleural fold, and two dark lines and dots on each sternite as in the imago. In most nymphs, the posterior abdominal segments are darker than the anterior ones, especially on the ventral surface.

Tails—Yellowish to very light tan, slightly darker at base and with several dark brown bars in the distal two-thirds. Almost bare basally and at tip, moderately long hairs in intervening space.

Holotype—Male imago—Reared. Hamburg Lake, N. C., March 15, 1930. No. 1093. 1 in C. U. collection.

Allotype—Female imago—Reared. Hamburg Lake, March 15, 1930. No. 1093. 2 in C. U. collection.

Paratypes—9 male imagoes, 7 female imagoes, 2 male subimagoes, 1 female subimago—All reared. Big Alamance Creek, N. C., at Tom's Place, March 24–27, and April 11, 1930; Inlet of Scales Lake, N. C., March 27, 1930; Trib. Reedy Fork River, N. C., March 21, 1930. No. 1093. 3–21 in C. U. collection.

This was the most abundant early spring species of Ephemerella in the piedmont area. Nymphs were collected, and many imagoes reared, from a number of streams in the vicinity of Greensboro during the spring of 1929 and again in 1930. Locations and dates of collections are as follows. Big Alamance Creek, about fourteen miles south of Greensboro, and a tributary of this stream, on March 10, 1929, and on many succeeding dates, both in 1929 and 1930; the outlet of Hamburg Lake,

about ten miles north of Greensboro, April 5, 1929, and succeeding dates; Middle Belew's Creek near the station of Belew Creek, March 31, 1929; Big Alamance Creek at Tom's Place, April 13, 1929; and several later dates; a tributary of the Uharie River near Farmer, April 2, 1929; the inlet to a private lake on the Scales estate near Greensboro, March 25, 1930; a small tributary of Reedy Fork River near Guilford Battleground, on April 17, 1930.

A large nymph, quite similar to that of *E. inconstans*, but seeming to differ slightly from it, was taken from Polecat Creek south of Greensboro on April 5, 1930.

Ephemerella catawba, sp. nov.

MEASUREMENTS

	BODY	TAILS	FOREWING	FORELEG
Male nymph (2 specimens)	5½–7	3½		
Female nymph (17 specimens)	5–7	3½–5		
Male imago (2 specimens)	6½–7	9–10	7	6–6½

A member of the *invaria* group. Seemingly distinguished from other species of this group by the lack of spines on the penes. Tails white, joinings purple. Thorax of male red-brown, abdomen olive-brown dorsally. Nymph slender, smooth, in life olive-green to brown in color. A 'moss-dweller.' Apparently has two color phases.

Male imago

Head—Light brown. Compound eyes light orange in upper portion.

Thorax—Reddish brown. Pronotum margined laterally with light yellow. Mesonotum marked and blotched with yellow. Sclerites of pleura brown, intersegmental spaces yellow. Metanotum and mesonotal spine darker brown. Antecoxal pieces of foreleg white, prosternum light yellowish brown. Mesosternum light brown in anterior portion, remainder dark reddish brown. Metasternum shaded with purple at anterior margin.

Legs—Foreleg light reddish brown, claw and last two tarsal segments greyish. Other legs yellowish white, claws and tarsi washed with light brown.

Wings—Hyaline. Forewing brown at base. Veins colorless except the three big veins on the costal border, which are tinged with yellow. Stigmatic area opaque, cross veins anastomosed.

Abdomen—Dorsally, olive brown with purplish brown markings on tergites 1–6. Tergites 7–9 light chestnut brown, 7 marked on each side of median line with purplish brown. Posterior margins of each darker brown, anterior margins yellowish. Tergites 1–6 shaded in central portion with darker markings of purplish brown. Median line faintly greyish white. Sternites 1–6 greyish white, washed with lavender; sternite 1 marked with chestnut brown on anterior margin and along lateral borders. Pleural fold greyish white. An indistinct darker dot on each side of median line near the center, also fainter oblique dashes at the anterior margin. Ganglionic area of each, grey-white.

Genitalia—See Pl. 9, Fig. 3. A very weak spine is present on one side of the penes of one specimen; the other lacks spines completely. This character should distinguish the species from others of the same group.

Tails—Smoky white at base, becoming silver white for most of their length. Joinings purple.

Nymph

Slender, smooth. In life olive-green to brown, changing to reddish-brown in alcohol. Apparently two color phases, one with large white patches on abdominal tergites 4–7.

Head—Yellowish white patches around each compound eye, laterad of each lateral ocellus and cephalad of the median ocellus. Vertex and occiput often mottled. Antenna brown, in some specimens darker at base. Mouthparts very similar to others of the *invaria* group.

Thorax—Pro- and mesonotum often considerably mottled with yellow and brown markings. Pleura yellow; sternites light red-brown.

Legs—Yellowish brown with darker brown markings. Femur with longitudinal brown band near center, another on each margin. Numerous rather long orange-brown spines on upper surface, mainly toward distal end and along hind margin. Tibia dark brown basally, lighter brown in distal half. Tarsus dark brown except a yellow basal band. Claw slender. See Pl. 9, Fig. 11c.

Abdomen—No dorsal spines. Postero-lateral margins considerably flattened and expanded, the outer margins serrate; postero-lateral angle prolonged into a sharp spine. Dark reddish brown. The flattened lateral margin yellow in light forms; in dark specimens, red-brown except for yellow spine. One color phase has whitish patches on tergites 4–7, bordering the gills. Posterior margin of each narrowly darker. Ventrally lighter red-brown, usually without markings.

However, one specimen exhibits a few laterally placed whitish blotches on the central sternites.

Gills—Purplish grey, an oval lighter area in center of each.

Tails—Yellowish to reddish brown, crossed by several narrow bands of yellow. In basal half, spines at joinings; distally fringed with short hairs.

Holotype—Male imago—Reared. Catawba River at Andrews Geyser, N. C., June 21, 1929. No. 1094. 1 in C. U. collection.

Paratypes—Male imago—Reared. Tributary of the Dan River at Cascades, N. C., May 10, 1930.

Nymphs—12 from Ocona Lufty River, June 22, 1930; 6 from Cascades, May 3, 1930. No. 1094. 2–14 in C. U. collection.

The slim olive-brown nymphs of this species were quite numerous crawling about in the moss on rocks in the stream at Cascades, near Danbury, on May 12, 1929. None of these were reared. However, from other nymphs collected on May 3, 1930, one male imago transformed.

[To be continued]

EXPLANATION OF PLATES

PLATE 5

OREIANTHUS PURPUREUS

Fig. 1. Mature nymph, dorsal aspect.
Fig. 2. Left mandible of nymph.
Fig. 3. First leg of nymph.
Fig. 4. Second leg of nymph.
Fig. 5. Third leg of nymph.
Fig. 6. Genitalia of male subimago, dissected out from mature nymph.
Fig. 7. Hypopharynx of nymph.
Fig. 8. Labium of nymph.
Fig. 9. Labrum of nymph.
Fig. 10. Right mandible of nymph.
Fig. 11. Wings of female imago.
Fig. 12. First leg of female imago.
Fig. 13. Second leg of female imago.
Fig. 14. Third leg of female imago.
Fig. 15. Maxilla of nymph.

PLATE 6

NEOCLOEON ALAMANCE

Fig. 1. Nymph, not yet fully mature. Dorsal aspect.
Fig. 2. Right mandible of nymph.
Fig. 3. Labrum of nymph.
Fig. 4. Hypopharynx of nymph.
Fig. 5. Right maxilla of nymph.
Fig. 6. Detailed sketch of canines, right mandible of nymph.
Fig. 7. Plates of 10th sternite of female imago, with apical margin of 9th sternite.
Fig. 8. Head of male imago, lateral aspect.
Fig. 9. Labium of nymph.
Fig. 10. Genitalia of male imago, dorsal aspect. Basal joint of forceps stippled lightly; chitinized structures stippled more heavily; openings of vasa deferentia unstippled.
Fig. 11. Left mandible of nymph.
Fig. 12. Detailed sketch of canines, left mandible of nymph.
Figs. 13–17. Gills of left side of body of nymph. In order, taken from segments 1, 2, 4, 5, 7.
Fig. 18. Left wing of male imago.

PLATE 7

Fig. 1. Genitalia of male subimago, *Habrophlebia pusilla*.
Fig. 2. Maxilla of nymph, *Leptophlebia swannanoa*.
Fig. 3. Genitalia of male imago, *Leptophlebia swannanoa*.
Fig. 4. Canines and lacinia of left mandible of nymph, *Habrophlebia pusilla*.
Fig. 5. Left mandible of nymph, *Habrophlebia pusilla*.
Fig. 6. Fifth gill of Leptophlebia nymphs: a. *L. swannanoa*. b. *L.* sp? No. 1.
Fig. 7. Outer apical angle of maxilla of nymph, *Haprophlebia pusilla*. See Fig. 26.
Fig. 8. Hind wing of male subimago, *Habrophlebia pusilla*.
Fig. 9. Genitalia of male subimago, *Habrophlebia pusilla*.
Fig. 10. Maxilla of nymph, *Leptophlebia* sp? No. 1.
Fig. 11. Apical margin of 9th sternite of female imago, *Leptophlebia swannanoa*.
Fig. 12. Left and right mandibles of nymph, *Leptophlebia swannanoa*.
Fig. 13. Genitalia of male imago, *Leptophlebia swannanoa*. Lateral aspect.
Fig. 14. Labial palp of nymph, *Leptophlebia guttata*.
Fig. 15. Labium of nymph, *Habrophlebia pusilla*.
Fig. 16. Right mandible of nymph, *Leptophlebia adoptiva*.
Fig. 17. Right mandible of nymph, *Leptophlebia mollis*.
Fig. 18. First gill of nymph, *Habrophlebia pusilla*.
Fig. 19. Fourth gill of nymph, *Habrophlebia pusilla*.
Fig. 20. Upper portion of mandible of nymph, *Leptophlebia guttata*.
Fig. 21. Second leg of nymph, *Potamanthus* sp? No. 1.
Fig. 22. Maxilla of nymph, *Potamanthus* sp? No. 1.
Fig. 23. Right mandible of nymph, *Potamanthus* sp? No. 1.
Fig. 24. Color pattern of fourth tergite of nymph, *Potamanthus* sp? No. 1.
Fig. 25. Labrum of nymph, *Potamanthus* sp? No. 1.
Fig. 26. Maxilla of nymph, *Habrophlebia pusilla*.

PLATE 8

GENUS BLASTURUS

Fig. 1. Apical margins of 9th sternites of female imagoes:
a. *B. gracilis.*
b. *B. collinus.*
c. *B. grandis.*
d. *B. austrinus.*

Fig. 2. Color patterns of fifth abdominal segment of nymph, *B. grandis.*
a. Fifth tergite.
b. Fifth sternite.

Fig. 3. Color patterns of pronotum of nymphs:
a. *B. grandis.*
b. *B. intermedius.*
c. *B. austrinus.*

Fig. 4. Details of penes of male imago, *B. grandis.* See Fig. 11.

Fig. 5. Color patterns of fifth tergites of male imagoes:
a. *B. grandis.*
b. *B. cupidus.*
c. *B. gracilis.*
d. *B. austrinus.*
e. *B. nebulosus.*

Fig. 6. Genitalia of male subimago, *B. collinus.*

Fig. 7. Third pair of gills of nymph, *B. intermedius.*
The two-lobed gill is the under one of the pair in this and other figures of gills.

Fig. 8. Genitalia of male imago, *B. cupidus.*

Fig. 9. Third pair of gills of nymph, *B. collinus.*

Fig. 10. Third pair of gills of nymph, *B. gracilis.*

Fig. 11. Genitalia of male imago, *B. grandis.*

Fig. 12. Third pair of gills of nymph, *B. austrinus.*

Fig. 13. Third pair of gills of nymph, *B. grandis.*

Fig. 14. Genitalia of male imago, *B. gracilis.*

Fig. 15. Third pair of gills of nymph, *B.* sp? No. 2.

Fig. 16. Color pattern of fifth tergites of nymphs:
a. *B. gracilis.*
b. *B. intermedius.*

Fig. 17. Genitalia of male imago, *B. nebulosus,* a) Details of penes; b) genitalia as a whole.

Fig. 18. Color patterns of fifth tergites of nymphs:
a. *B. austrinus.*
b. *B. collinus.*
c. *B.* sp? No. 1.
d. *B.* sp? No. 2.

Fig. 19. Genitalia of male subimago, *B. intermedius.*

Fig. 20. Color pattern of fifth tergites of nymphs:
a. *B. cupidus.*
b. *B. nebulosus.*
Fig. 21. Genitalia of male imago, *B. austrinus.*
a. Details of penes.
b. Genitalia as a whole.

PLATE 9

GENUS EPHEMERELLA

Fig. 1. Genitalia of male imago, *E. lata.*
Fig. 2. Left mandible of nymph, *E. wayah.*
Fig. 3. Genitalia of male imago, *E. catawba.*
Fig. 4. Penes of male imago, enlarged.—*E. inconstans.* Note variation from form shown in Fig. 23.
Fig. 5. Genitalia of male subimago, *E. conestee.*
Fig. 6. Crown of maxilla, much enlarged; nymph, *E. wayah.*
Fig. 7. Right mandible of nymph, *E. wayah.*
Fig. 8. Head of nymph, *E. conestee.*
Fig. 9. Upper portion of right mandible, of nymph, much enlarged—*E. wayah.*
Fig. 10. Foreleg of nymph, *E. longicornis.*
Fig. 11. Third claws of nymphs:
a. *E.* sp? No. 1.
b. *E.* sp? No. 2.
c. *E. catawba.*
Fig. 12. Labium of nymph, *E. wayah.*
Fig. 13. Maxilla of nymph, *E. wayah.*
Fig. 14. Head of nymph, *E. longicornis.*
Fig. 15. Claw of foreleg, much enlarged—nymph, *E. longicornis.*
Fig. 16. Claw of third leg of nymph, *E. conestee.*
Fig. 17. Foreleg of nymph, *E. conestee.*
Fig. 18. Foreleg of nymph, *E. wayah.*
Fig. 19. Claw of foreleg of nymph, *E. wayah.*
Fig. 20. Head of nymph, *E. wayah.*
Fig. 21. Maxilla of nymph, *E.* sp? No. 1.
Fig. 22. Genitalia of male imago, *E. longicornis.*
Fig. 23. Genitalia of male imago, *E. inconstans.* Compare with Fig. 4.
Fig. 24. Lateral abdominal spines of nymph, *E. inconstans.* Segments 2–9 shown, and part of 10.
Fig. 25. Outlines of distal portions of 9th sternites of female imagoes:
a. *E. wayah.*
b. *E. inconstans.*
c. *E. conestee.*
d. *E. longicornis.*
Fig. 26. Claw of third leg of nymph, enlarged,—*E. inconstans.*
Fig. 27. Genitalia of male imago, *E. tuberculata.*

PLATE 10

GENUS ISONYCHIA

Figs. 1–4. Apical margins of 9th sternites of female imagoes

Fig. 1. *I. notata.*
Fig. 2. *I. pacoleta.*
Fig. 3. *I. albomanicata.*
Fig. 4. *I. sicca*, var. *manca.*
Fig. 5. Third gill of nymph, *I. notata.*
Fig. 6. Genitalia of male imago, *I. similis.*
Fig. 7. 9th sternite of female imago, *I. annulata.*
Fig. 8. Third gill of nymph, *I. annulata.*

Figs. 9–12. Apical margins of 9th sternites of females.

Fig. 9. *I. similis.*
Fig. 10. *I. georgiae.*
Fig. 11. *I. serrata.*
Fig. 12. *I. aurea.*
Fig. 13. Tibial spines, tarsi and claws of forelegs of nymphs:
  a. *I. pacoleta.*
  b. *I. albomanicata.*
  c. *I. serrata.*
  d. *I. aurea.*
Fig. 14. Genitalia of male imago, *I. pacoleta.*
Fig. 15. Tibial spines, etc., of nymphs:
  a. *I. similis.*
  b. *I. notata.*
  c. *I. georgiae.*
  d. *I. manca.*
  e. *I. annulata.*
Fig. 16. Details of penes of male imago, *I. similis.*
Fig. 17. Details of penes of male imago, *I. obscura.*
Fig. 18. Claws of forelegs of nymphs, much enlarged:
  a. *I. aurea.*
  b. *I. similis.*
  c. *I. pacoleta.*
  d. *I. albomanicata.*
Fig. 19. Genitalia of male imago, *I. serrata.*
Fig. 20. Claws of forelegs of nymphs:
  a. *I. serrata.*
  b. *I. manca.*
  c. *I. georgiae.*
  d. *I. annulata.*
  e. *L. notata.*
Fig. 21. Details of penes of male imago, *I. annulata.*
Fig. 22. Details of penes of male imago, *I. serrata.*
Fig. 23. Genitalia of male imago, *I. annulata.*
Fig. 24. Genitalia of male imago, *I. obscura.*
Fig. 25. Genitalia of male imago, *I. sicca*, var. *manca.*

PLATE 11

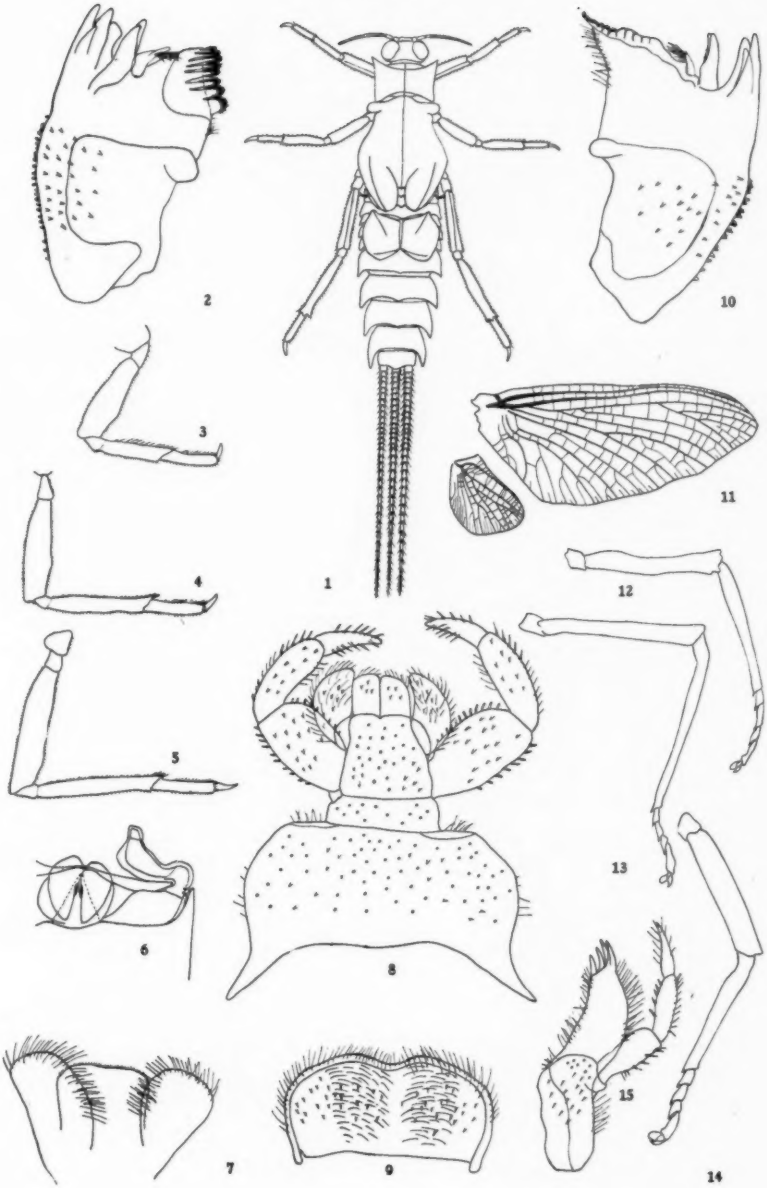
Fig. 1. Genitalia of male imago, *Siphlonurus marginatus*.
Fig. 2. Details of penes of male imago, *Siphloplecton speciosum*. See Fig. 19.
Fig. 3. Portion of foreleg of nymph, *Isonychia notata*. F, femur; Tb, tibia; Tar., tarsus.
Fig. 4. Portions of forelegs of nymphs of Isonychia, showing femoral flange and spines on base of tibia.
a. *I. aurea*.
b. *I. pacoleta*.
c. *I. serrata*.
d. *I. manca*.
e. *I. similis*.
f. *I. annulata*.
g. *I. georgiae*.
h. *I. albomanicata*
Fig. 5. Details of penes of male imago, *Siphloplecton signatum*. See Fig. 13.
Fig. 6. Details of penes of male imago, *Siphlonurus marginatus*. See Fig. 1.
Fig. 7. Third gill of nymph, *Isonychia albomanicata*.
Fig. 8. Third gill of nymph, *Isonychia similis*.
Fig. 9. Genitalia of male imago, *Siphlonurus decorus*.
Fig. 10. Third gill of nymph, *Isonychia manca*.
Fig. 11. Third gill of nymph, *Isonychia georgiae*.
Fig. 12. Third gill of nymph, *Isonychia aurea*.
Fig. 13. Genitalia of male imago, *Siphloplecton signatum*.
Fig. 14. Third gill of nymph, *Isonychia serrata*.
Fig. 15–16. Details of penes of male imago, *Siphlonurus decorus*, showing slight variations. See Fig. 9.
Fig. 17. Third gill of nymph, *Isonychia pacoleta*.
Fig. 18. Details of penes of male imago, *Siphlonurus decorus*. Lateral aspect.
Fig. 19. Genitalia of male imago, *Siphloplecton speciosum*.

PLATE 12

Fig. 1. Maxilla of nymph, *Ephemera blanda*.
Fig. 2. Maxilla of nymph, *Eurycaenis nitida*.
Fig. 3. Genitalia of male imago, *Baetis australis*.
Fig. 4. Hind wing of male imago, *Baetis australis*.
Fig. 5. Wing of female imago, *Eurycaenis nitida*.
Fig. 6. Maxilla of nymph, *Ameletus lineatus*.
Fig. 7. Left mandible of nymph, *Eurycaenis nitida*.
Fig. 8. Hypopharynx of nymph, *Eurycaenis nitida*.
Fig. 9. Genitalia of male imago, *Baetis* sp? No. 1.
Fig. 10. Right mandible of nymph, *Eurycaenis nitida*.
Fig. 11. Hind wing of female imago, *Acentrella ampla*.
Fig. 12. Maxilla of nymph, *Ameletus* sp? No. 2.
Fig. 13. Upper portion of right mandible of nymph, *Pseudocloeon carolina*.
Fig. 14. Labial palp of nymph, *Pseudocloeon dubium*.
Fig. 15. Genitalia of male imago, *Ephemera blanda*.

Fig. 16. Second and third gills of nymph, *Siphloplecton* sp? No. 1.
Fig. 17. Upper portion of right mandible of nymph, *Pseudocloeon dubium*.
Fig. 18. Apical margin of 9th sternite of female imago, *Siphlonurus decorus*.
Fig. 19. Apical margin of 9th sternite of female imago, and paired plates of 10th sternite.—*Baetis australis*.
Fig. 20. Apical margin of 9th sternite, and plates of 10th, of female imago, *Acentrella ampla*.
Fig. 21. Genitalia of male imago, *Acentrella ampla*.
Fig. 22. Frontal process of head of nymph, *Ephemera blanda*.
Fig. 23. Apical margin of 9th sternite of female imago, *Eurycaenis nitida*.
Fig. 24. Labrum of nymph, *Ephemera blanda*.
Fig. 25. Labrum of nymph, *Eurycaenis nitida*.
Fig. 26. Apical margin of 9th sternite of female imago, *Ameletus lineatus*.
Fig. 27. Labium of nymph, *Eurycaenis nitida*.
Fig. 28. Labial palp of nymph, *Pseudocloeon* sp?
Fig. 29-31. Apical margins of 9th sternites of female imagoes
Fig. 29. *Siphloplecton basalis*.
Fig. 30. *Siphloplecton speciosum*.
Fig. 31. *Siphloplecton signatum*.
Fig. 32. Maxillary palp of nymph, *Pseudocloeon* sp?
Fig. 33. Claw and distal portion of third leg of nymph, *Ephemera blanda*.

PLATE 5



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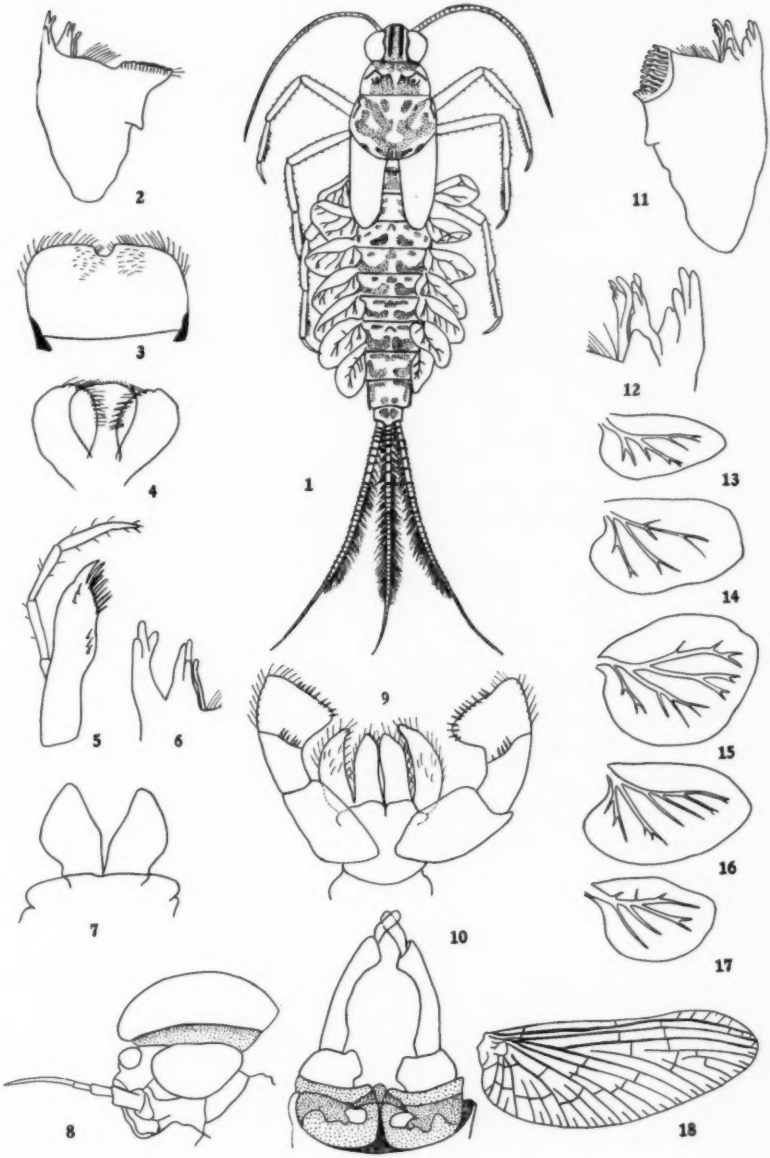

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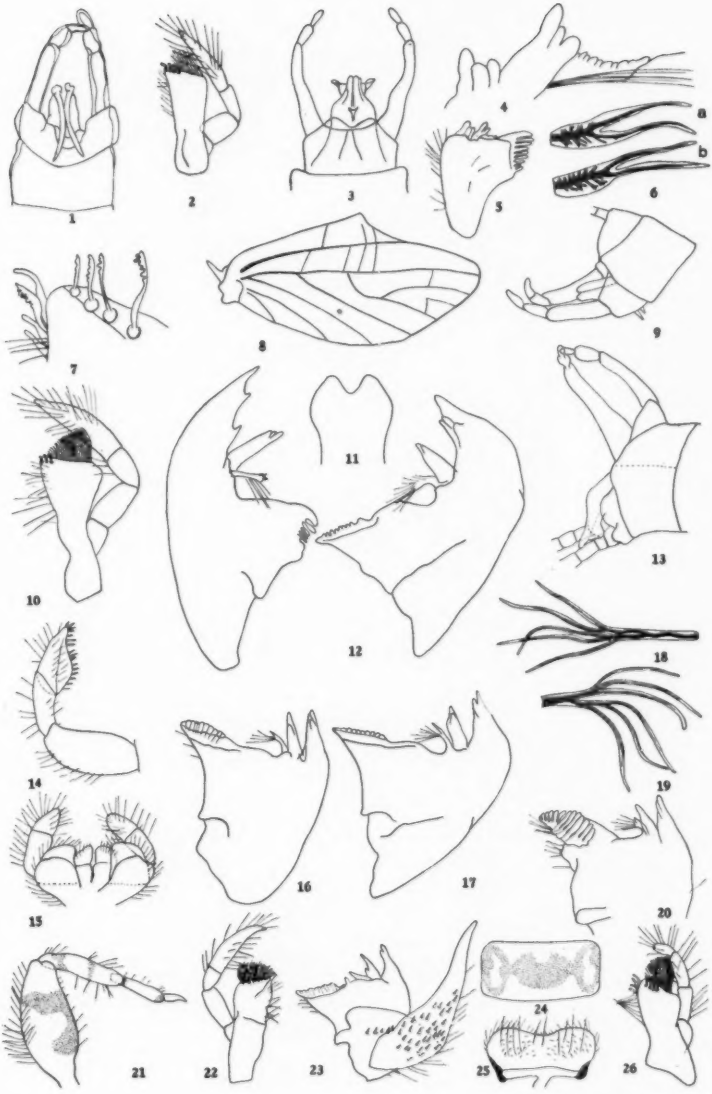

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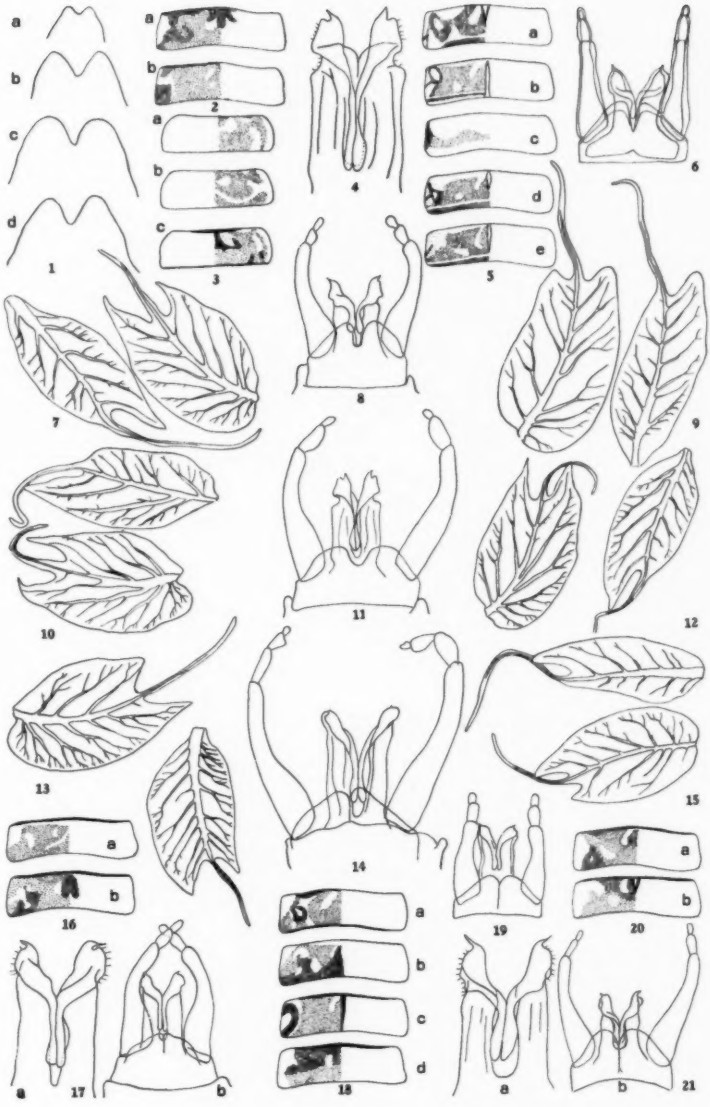

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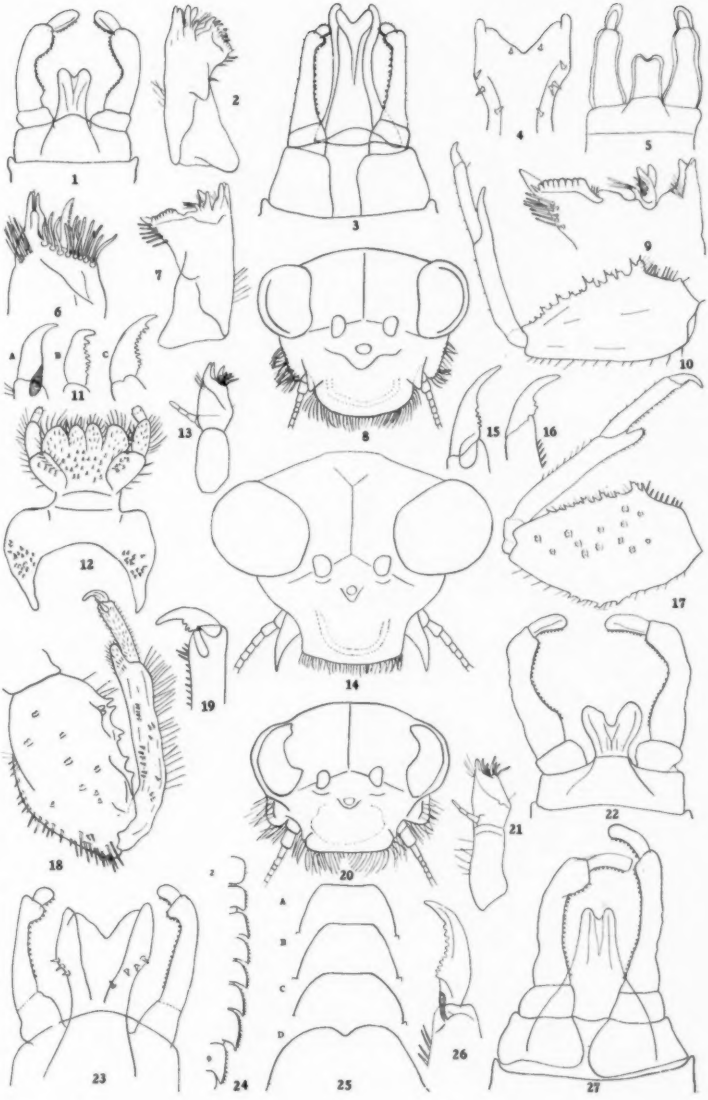

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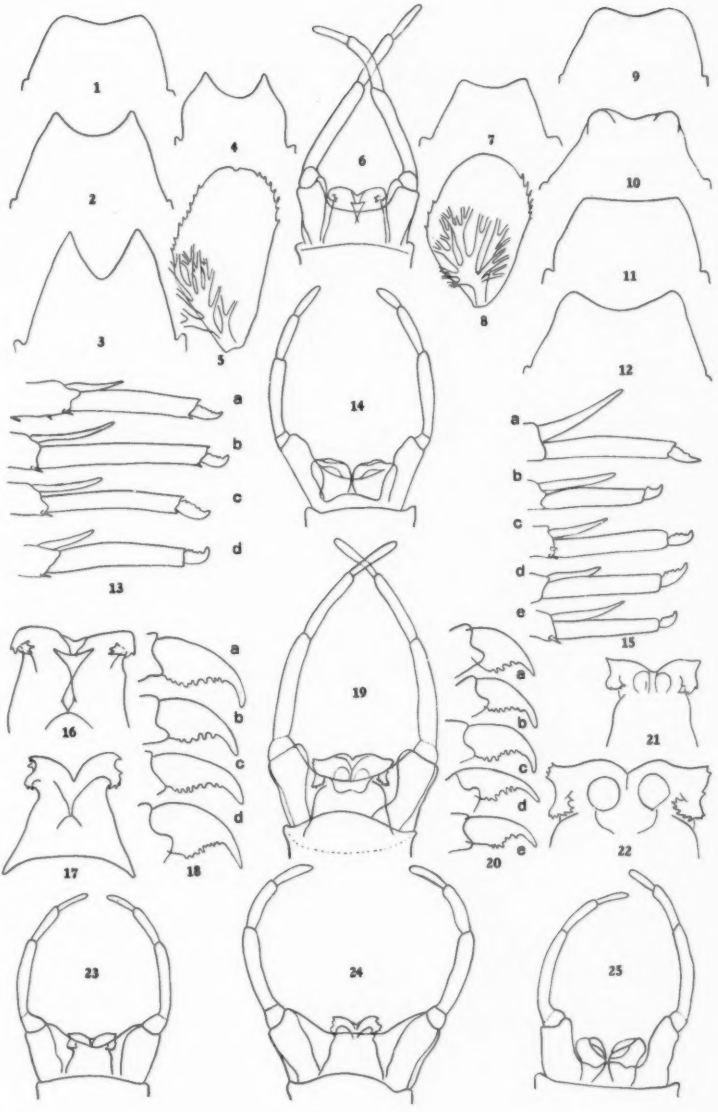
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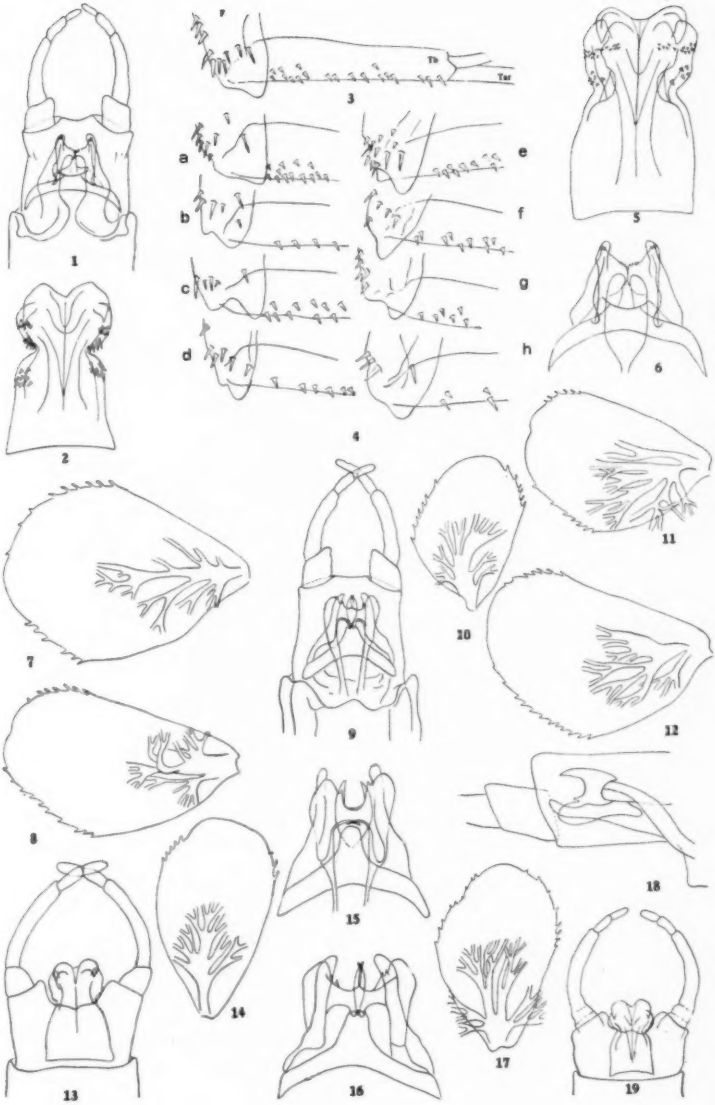
PLATE 11



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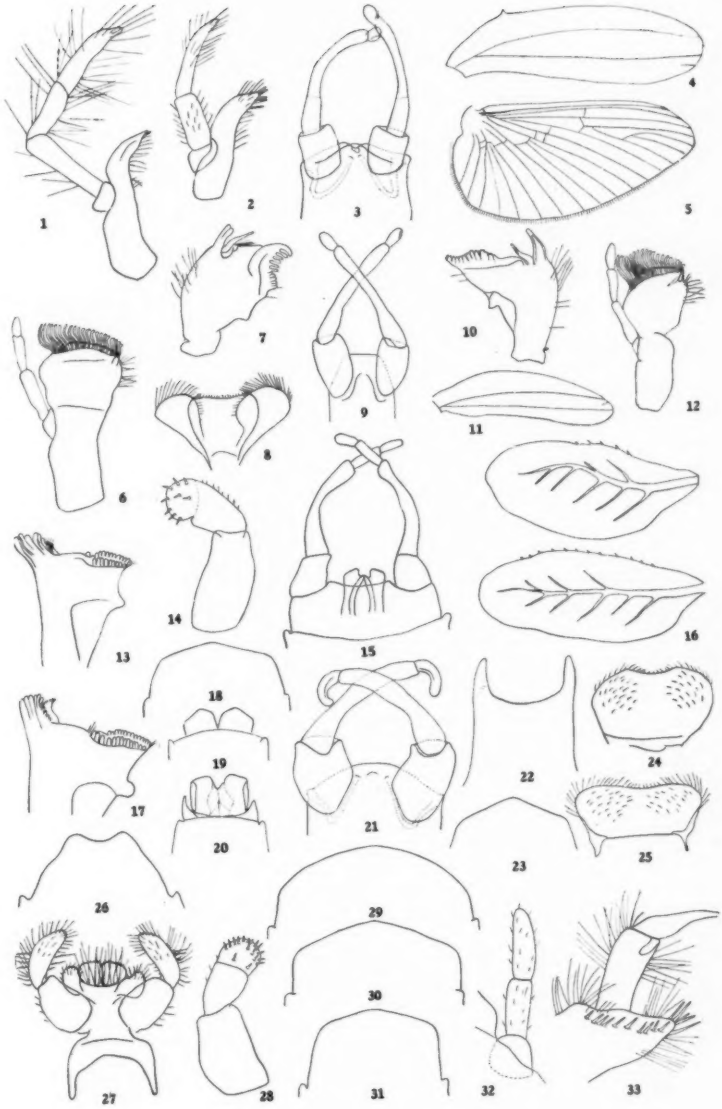
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